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Morphometric Analysis of Phytosaur Premaxillae and Maxillae

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Morphometric Analysis of Phytosaur Premaxillae and Maxillae

by

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Report

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Morphometric Analysis of Phytosaur Premaxillae and Maxillae

by

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The University of Texas at Austin, 2013

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When it comes to studying organisms, having size independent measures for maturity are important for many aspects of organismal biology, and may be crucial for determining taxonomic affinity, and morphological signals associated with ontogenetic age (i.e., juvenile vs. adult) and sexual dimorphism. This is because the size of an organism can be the result of many factors that are not necessarily indicators of maturity (Chabreck and Joanen, 1979; Ferguson, 1984; Mazzotti et al., 1986; Deeming and Ferguson, 1989; Brandt, 1991). This problem is particularly pronounced when researchers are studying extinct species.

The purpose of my research project was to investigate and understand patterns of morphological variation in the phytosaur premaxilla and maxilla and to determine the degree to which morphological variation is a result of ontogeny. For example, such

patterns might include the number, size and location of alveoli or the presence of prenarial crests. I conducted this research by gathering information on the premaxilla and maxilla of all phytosaur elements present in the University of Texas at Austin Vertebrate Paleontology Lab collection. I then performed statistical analysis on the data, and compared my results to those of previous authors to see if I could identify any ontogenetic signal.

I did not identify size-independent ontogenetic influence on morphology with certainty but I did find some possible features that merit additional investigation in future studies. Those include the presence of one to three diastemas located primarily at the anterior end of the premaxilla, a wide interpremaxillary fossa but small alveolar ridge, and alveoli whose size mirror the width of the premaxilla (for example wide areas in the premaxilla are associated with larger alveoli whereas narrow areas in the premaxilla are associated with smaller alveoli). My study also confirmed the previous findings of Hungerbühler (2002) that the alveoli of phytosaurs are heterodont and exist in three distinct location-specific patterns, and the work of other researchers that prenarial crests are present only in larger specimens (Camp, 1930; Ballew, 1986; Hungerbühler, 2002; Stocker, 2010).

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CHAPTER ONE: INTRODUCTION AND STATEMENT OF PURPOSE

When it comes to studying organisms, having size independent measures for maturity are important for many aspects of organismal biology, and may be crucial for determining taxonomic affinity, and morphological signals associated with ontogenetic age (i.e., juvenile vs. adult) and sexual dimorphism. This is because the size of an organism can be the result of many factors that are not necessarily indicators of maturity (Chabreck and Joanen, 1979; Ferguson, 1984; Mazzotti et al., 1986; Deeming and Ferguson, 1989; Brandt, 1991). This problem is particularly pronounced when researchers are studying extinct species.

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CHAPTER TWO: REVIEW OF LITERATURE

2a. Description of Phytosaurs

Phytosaurs are an extinct group of semi-aquatic reptiles that looked much like extant crocodiles. They had short legs, wide heavy bodies, armored plates in the skin, long tails, and narrow snouts with numerous teeth. The most obvious difference between the two groups is that crocodiles have their nostrils at the ends of their snouts, whereas in phytosaurs they were positioned on a raised hump in front of the eyes (Chatterjee, 1978). Though their morphology is similar they are part of two distinct lineages (Nesbitt, 2011). Phytosaurs are known exclusively from Late Triassic deposits. Phytosaurs are known mostly in the northern hemisphere including North America, Europe and Asia. Some specimens also were located in northern Africa and Madagascar (Chatterjee, 1987).

Although the name phytosaur means ‘plant lizard’ phytosaurs are hypothesized to have been carnivorous because of the presence of numerous sharp-pointed, conical, and polyphyodont teeth, and eyes that were positioned close to the mid-line (suggesting predatory binocular vision) (Catterjee, 1987 and Hungerbühler, 2000). The teeth of most phytosaurs were replaced in a wave-like replacement pattern with the direction being from back-to-front (Edmund, 1960). A few specimens from India, however, show a clear sequence of back-to-front replacement waves with replacement teeth increasing in size in alternate series towards the rear (Chatterjee, 1978). Further evidence of a carnivorous lifestyle of phytosaurs comes from small bipedal archosaurs found in the stomachs of some fossilized specimens (Chatterjee, 1978). The position of the eyes and nostrils set high in the skull may have given phytosaurs an advantage over their prey at the water's edge because they could lay, breathe, and see while almost totally submerged (Chatterjee, 1978). Their narrow snout was well suited for catching swift-swimming fish by a sideways sweep of the head and then a twist of its powerful jaw (Chatterjee, 1978). Enlarged anterior fang-like teeth probably were used for stabbing smaller prey, whereas the strong posterior premaxillary teeth likely were used to seize and subdue larger sized prey as the maxillary teeth dismembered it (Hungerbühler, 2000). Because phytosaurs were so supremely suited for their semi-aquatic lifestyle some authors expressed surprise that they went extinct at the end of the Triassic (Chatterjee, 1978; Carroll, 1988) and left no decedents, whereas Crocodylia did.

Gathering evidence for sexual dimorphism within phytosaurs was difficult because of insufficient sample sizes (Stocker, 2010). However, there are some features of phytosaurs that have been hypothesized to show sexual dimorphism. For example flat nostrils may represent males while rimmed nostrils may represent the females (Camp, 1930; Zeigler et al., 2002). One published hypothesis is that sexual dimorphism was typically present in the cranial structure and was used for visual display (Zeigler et al., 2002). For example, males had hypertrophied cranial structures that could be seen easily by other members of the species. Slight variability in the brain cases of different specimens was documented previously (Chatterjee, 1978), and the presence of a crested rostrum previously was attributed to sexual dimorphism (Camp, 1930; Colbert, 1947; Gregory, 1962; Hunt, 1989).

Juvenile (morphologically and ontogenically immature) phytosaurs typically were identified by their relatively small size (Chatterjee, 1987; Elder, 1987; Rieppel 1992; Fara and Hungerbüler, 2000; Maisano 2002; Lucas et al., 2007). Juvenile phytosaurs may have external nares that are anterior to the antorbital fenestrae and that shifted posteriorly and dorsally through ontogeny (Padian, 1994), but no data supports that claim. *Paleorhinus magnoculus* was identified as a juvenile because of its relatively large orbits, short snout, and overall small size (Fara and Hungerbühler, 2000).

2b. Phylogeny

During the Triassic a wide diversity of archosauriforms was present on nearly every continent and in most environments. Taxa included Rauisuchia, Aetosauria, Phytosauria, *Vancleavea*, Pterosauria, Ornithischia, Sauropodomorpha, Crocodylomorpha, and Dinosauria. The major split within Archosauria was between the crocodilian and avian lineages. Phytosaurs, aetosaurs, ornithosuchids, various 'rauisuchians' and crocodylomorphs were placed as part of the crocodilian lineage and pterosaurs, *Marasuchus*, and dinosaurs were placed as part of the avian lineage (Gower and Wilkinson, 1996).

The placement of phytosaurs within these lineages was never clear. Most previous researchers placed phytosaurs as the most basal clade of pseudosuchians (Gauthier, 1984;

Benton and Clark, 1988; Sereno, 1991; Irmis, 2007) or one node closer to Crocodylomorpha than Ornithosuchidae (Parrish, 1993). The latest phylogenetic analysis, however, placed phytosaurs as the most proximal outgroup to Archosauria (Nesbitt, 2011).

Some of the evidence that places phytosaurs outside Archosauria is derived from analysis of skull morphology. In other archosaurs the palatal processes of the maxilla meet at the midline. In phytosaurs, however, the palatal processes of the maxillae do not meet at the midline, and are at least divided by the premaxillae. In addition, Archosaurs have an elongated and tabular lagenar/cochlear recess in their braincases whereas the lagenar/cochlear recess in the braincases of phytosaurs is shallow. Also, the external foramen for the abducens nerve sits at the border between the prootic and the sphenoid in phytosaurs and other non-archosaurian archosauromorphs, but is formed only within the prootic within archosaurs, at least primitively (Nesbitt, 2011).

There also are postcranial archosaur synapomorphies that phytosaurs lack. For example, unlike archosaurs, phytosaurs lack coracoids with postglenoid processes, distinct anteromedial tubers, and a distal tarsal four with a distinct, proximally raised region on the posterior portion. The posteroventral portion of the coracoid of phytosaurs is thin and lacks a ‘swollen’ tuber, but in archosaurs there is a distinct, thickened edge and muscle scar. Those features helped to place phytosaurs closer to *Euparkeria* than to archosaurs (Nesbitt, 2011). Also, like *Euparkeria*, phytosaurs lack a distinct lateral tuber on the proximal portion of the ulna. Instead, they possess a simple convex lateral margin of the ulna. In addition, phytosaurs, *Euparkeria*, and *Proterosuchus* have long metacarpals relative to metatarsals (longer than half the length of the longest metatarsal) but archosaurs have short metacarpals relative to metatarsals (this condition is not clear in basal avian-line archosaurs). Finally, orientation of the calcaneal tuber of phytosaurs and *Euparkeria* is about 45^{o} posteriorly relative to the transverse plane, but is between 50^{o} and 90^{o} (closer to 90^{o}) in ornithosuchids, suchians, and the avian-line archosaurs *Marasuchus* and *Pseudolagosuchus* (Nesbitt, 2011).

2c. Determining Morphological and Ontogenic Maturity

One of the issues facing paleontologists today is the need to distinguish between adults and juveniles within the same taxon. This is difficult particularly for extinct species because ontogeny and the associated morphological changes are not always well documented or easily interpretable in the fossil record. In addition, morphological changes that suggest immaturity could be a result of other factors. For example, although it is tempting to look at size as a method to determine maturity that practice is laden with problems because size can vary greatly depending on nutrition, sexual dimorphism, climate, food availability, incubation temperature, population density, dwarfism, or illness (Chabreck and Joanen, 1979; Ferguson, 1984; Mazzotti et al., 1986; Deeming and Ferguson, 1989; Brandt, 1991). Ideally, size-independent measures of morphological maturity would aid in establishing the ontogenetic age of extinct species because those measures would be free from many of the issues listed above. Several researchers previously investigated these types of measures.

One such potential size-independent maturity index is neurocentral sutures in crocodylian vertebral columns (Brochu, 1996). In crocodylians the sutures between the neural arches and centra remain visible late into ontogeny, and they close in a caudal-to-cranial sequence (Mook, 1921; Hoffstetter and Gasc, 1969; Frey, 1988; Brochu 1992a; Brochu, 1992b). If this is the case than the extent of neurocentral suture closure would be a reasonable indicator of estimate ontogenetic maturity. This could be beneficial to scientists not only studying extant species but extinct ones as well because in most deposits vertebrae are typically more numerous than other postcranial skeletal elements, and these particular sutures are relatively easy to see and identify (Brochu, 1996). In four extant crocodylian species caudal-to-cranial progression of neurocentral suture closures has been observed and the number of suture closures increased with an increase in maturity index and geometric mean (body size) (Brochu, 1996).

Other authors continued this line of research by examining if the same posterior-to-anterior suture closure pattern present in extant crocodylians is also present in their extinct relatives (Irmis, 2007; Renesto, 2008). If so, this would provide both a size-independent measure for determining ontogeny of archosaurs in the fossil record as well as confirm whether the neurocentral suture closure pattern is plesiomorphic for Pseudosuchia or Archosauria. Archosauria is a large and diverse clade in which different patterns of neurocentral suture closures could exist for different groups. Birds are known to have the opposite patterning in their ontogeny (anterior-to-posterior neurocentral suture closures; (Stark, 1993), and, therefore, it is foreseeable that other archosaurians would as well.

In phytosaurs, suture closures increased as the geometric mean (body size) increased (Irmis, 2007). These results match the suture closure pattern of extant crocodylians and therefore help support the hypothesis that suture closures may be a good indicator of size (and thus maturity) (Irmis, 2007). The same pattern of neurocentral suture closures not only exists for North American phytosaurs (Irmis, 2007) but also their European counterparts (Renesto, 2008).

Another method to determine the morphologic maturity of phytosaurs is by comparing the size ratios of specific cranial features such as skull length, orbit diameter, preorbital length (snout), prenarial length, prenarial width, postorbital length, and skull width (estimates) among adult and suspected juvenile basal phytosaurs (Fara and Hungerbühler, 2000). The suspected juveniles have a larger proportion of orbit diameter relative to skull length, a more slender rostrum and a shorter snout length than their adult counterparts (Fara and Hungerbühler, 2000).

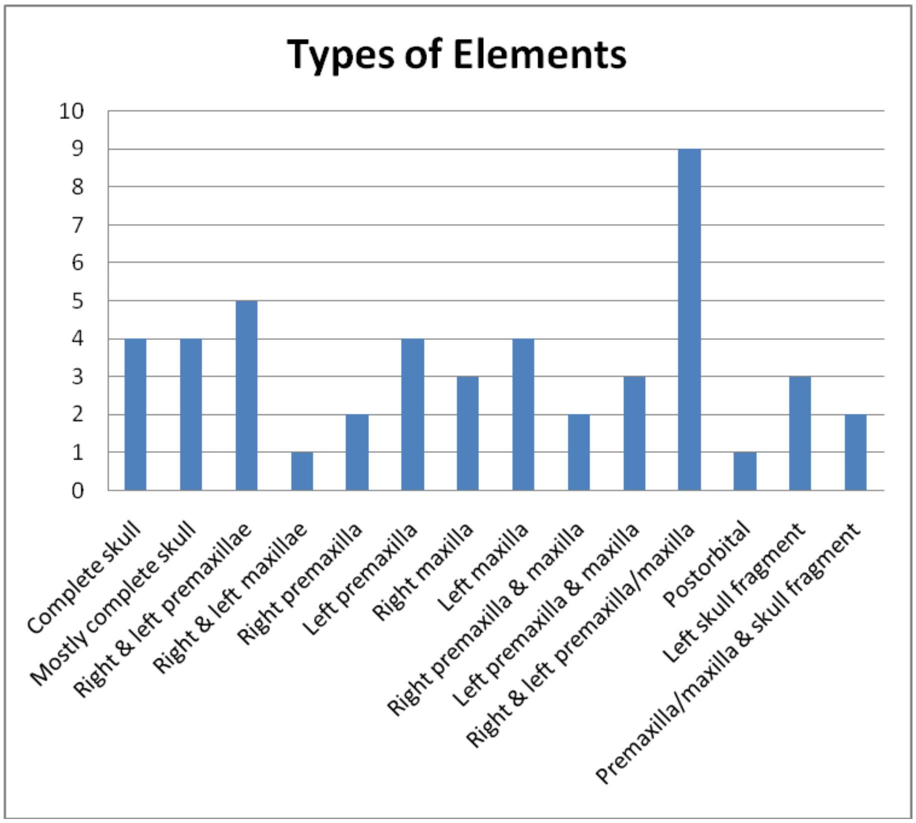
CHAPTER THREE: MATERIALS AND METHODS

3a. Construction of the Database

I constructed a database of 48 specimens of phytosaur maxillae and premaxillae in Microsoft Excel (Appendix 1) using specimens from Vertebrate Paleontology Laboratory at The University of Texas at Austin (TMM). All specimens are housed and were examined at The University of Texas Vertebrate Paleontology Laboratory in Austin in the summer and fall of 2012. I collected and analyzed data from the premaxilla and maxilla as well some postorbital skull features. I identified each specimen with either its catalogue number or field number and wrote a description of the material being analyzed (element, side). When possible, I also recorded any taxonomic information along with the locality information and geographic area in which the specimen was found. All this information was provided to me on cards that had been previously created by the person who prepared the sample or by the collection manager, and that are housed with the specimens. I also recorded in which cabinet and drawer the specimen is located in the Vertebrate Paleontology Laboratory to make it easier to locate those specimens later for further study.

3b. Types of Elements

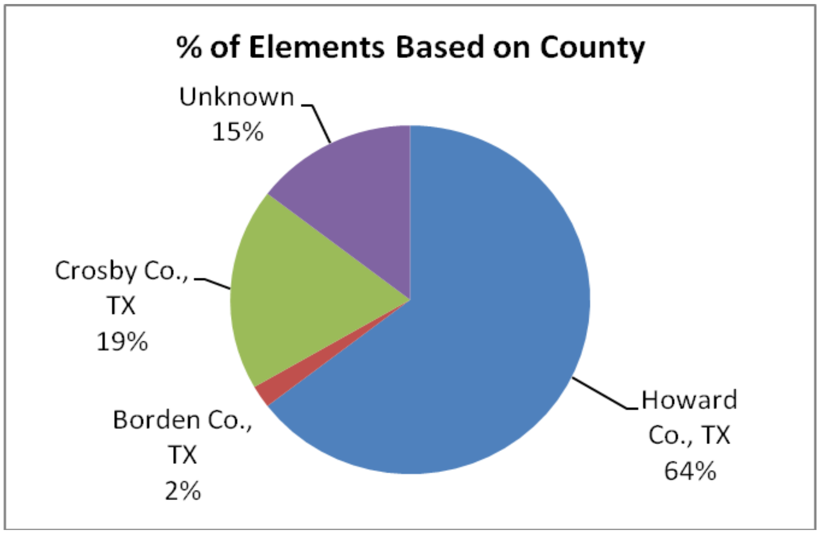
For each specimen I recorded the type of element. I also recorded the number of specimens that had each specific element in order to see which elements were the most common in the collection (see Graph 3b.1). I measured the specimen if it was in moderate to good condition; that includes specimens with little to no matrix and little to no plaster covering the bone. Broken and restored bones also were included as long as the element was in good enough condition to take measurements. Some specimens had to be excluded because they were coated in too much matrix or were too crushed to obtain information about the number, size, and shape of the alveoli (tooth sockets). Overall, 40 different data points were collected. These included data on the lengths and widths of different alveoli, postorbital measurements, and qualitative observations about the specimens (i.e. condition of the bones).

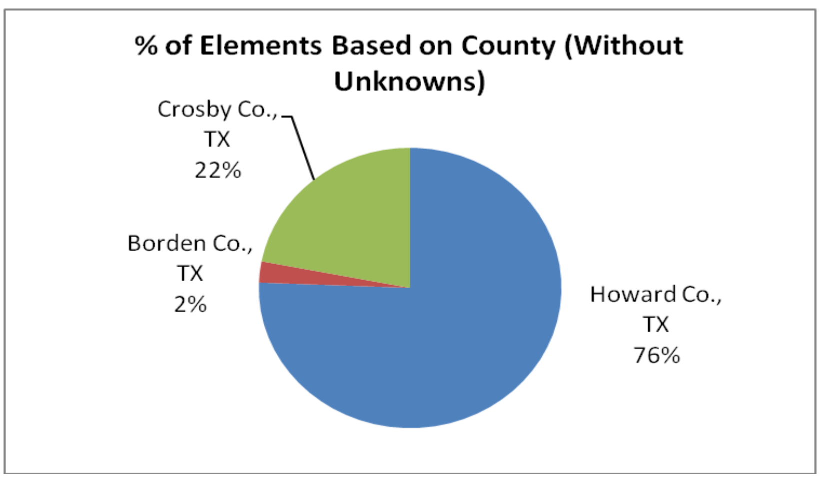


Graph 3b.1: Number of specimens in this study containing each of the types of elements recorded in Appendix 1.

3c. Location of Specimens

Of the 48 specimens included in this study all the samples came from Howard, Crosby, or Borden County, Texas. Fifteen percent of the samples lacked locality data and, therefore, I could not place where they were from.





Graph 3c.1 and 3c.2: The percentages of elements obtained from Howard, Crosby, or Borden County, Texas with and without unknowns. In both cases the majority of elements are from Howard County, Texas.

3d. Method for Taking Measurements

I first began by counting the number of alveoli in each specimen. I counted an alveolus as being present if there was a round indention in the ventral portion of the premaxilla or maxilla. In some cases plaster or matrix had filled these indentions but the presence of the different material was enough to determine that an alveolus may have been present. In those situations I often used a Wild Heerbrugg Type 376788 microscope to help determine whether an alveolus was in fact present. In situations when the alveoli were partially exposed, were in too poor condition to make a completely accurate count, or when the tooth-bearing element was incomplete, I used the phrase 'at least' to indicate that there could be more alveoli than those I had positively identified but I was not able to recorded any additional alveoli with certainty. I recorded the alveolar data into separate categories for the right and left side as well as for the premaxilla and maxilla. I also recorded the total number of right and left alveoli by adding up the number of observed premaxillary and maxillary alveoli for specimens that had both elements from a single side.

I also recorded the length and width of selected alveoli. I took measurements for each alveolus in millimeters to the nearest hundredth using six-inch digital calipers from Cen-tech. Because the digital calipers are limited to only measuring to the hundredths place I took each measurement three times and then averaged the points to get a more accurate reading. I used the same procedure to also measure the width of the premaxilla.

I used a cross-section of specific alveolar lengths and widths to capture the disparity of dentition in my sample. My selections of which alveoli to include were based on personal observations and the results of Hungerbühler (2000). There are three distinct dental sets in the upper jaw (Hungerbühler, 2000). The tip-of-snout set has large fang-like anterior most teeth. The premaxilla set have teeth that grade from an mesial, conical, unspecialized, forms to distal high, D-shaped, bicarinate teeth. In the maxilla the teeth grade from medial stout, conical and unspecialized forms to distal triangular forms. Counting from mesial to distal, I selected the second, fourth and fifteenth premaxillary alveoli to study in more detail. I selected the second premaxilla alveolus because it represents one of the tip-of-snout fanglike anterior teeth. I selected the fourth premaxillary alveolus because it represents one of the anterior premaxillary conical, unspecialized forms. I selected the fifteenth premaxillary alveolus because it represents one of the posterior high, D-shaped, bicarinate teeth.

Other measurements I made were the width of the right and left sides of the premaxilla taken at three different locations. Those locations were selected to capture the width disparity I observed along the rostrum, comparable to date reported by Hungerbühler (2000). The first measurement I took was at the second premaxillary alveolus because I observed that this tends to be one of the widest parts of the phytosaur premaxillae because of the expansion of the premaxilla at the point of the terminal rosette. I next measured between the fourth and fifth premaxillary alveolus because I observed that that area tends to be one of the narrowest parts of the premaxillae because of the constriction posterior to the terminal rosette. Finally, I measured width at the premaxilla-maxilla suture.

I also made a fourth width measurement for the total width across both premaxillae. Unlike the other measurements that were taken of the right and left premaxillae separately, this measurement incorporated both the right and left premaxillae together. I made this measurement at the seventh premaxillary alveolus because I observed that unlike the location at the second or fourth/fifth alveoli it seemed more indicative of the average width of the phytosaur premaxillae (see also Hungerbühler, 2000).

I took the following skull and premaxilla/maxilla measurements in millimeters to the tenths place with a seamstress tape measure. Unfortunately, all those measurements were less precise than those I had taken with the digital calipers (which can be used to measure to the hundredths instead of tenths place) but because of the size of the skull measurements the digital calipers were too small. All measurements were taken three times and then averaged.

I measured the prenarial length from the anterior-most edge of the naris to the anterior-most edge of the premaxilla. The maxillary length I measured from the premaxilla-maxilla suture to the ventral edge of the maxilla-jugal suture on the lateral surface of the element. I took the postorbital width from the edge of the posterior-most portion of the left orbit to the same position on the right orbit. I measured the anterior/posterior orbit diameter from the middle of the anterior-most to the posterior-most portion of the orbit. Only one of the orbits was used for this measurement depending on whether the right or left orbit was in better condition. I measured the skull width from the lateral edges of each quadrate across the dorsal surface of the skull. I took the measurement of the post-orbital length of the skull from the posterior-most portion of the orbit to the posterior-most portion of the posterior process of the squamosal. This measurement was taken only on one side of the skull based on whether the right or left side was in better condition. Last, I measured the total skull length from the anterior-most edge of the premaxilla to the posterior-most edge of the posterior process of the squamosal.

The following characteristics I recorded as either being present or absent. First, I noted the presence of an alveolar ridge, along with its size (relatively large or small) if present. Second, I noted the presence or absence of the interpremaxillary fossa and its relative width; narrow or wide. Third, I recorded the presence or absence of a diastema and which alveoli it was found between or near. Additionally, I recorded whether a prenarial crest was absent or present.

I also took descriptive data on whether or not the alveoli appeared uniform (homodont dentition), if they appeared crushed and if so in what direction (dorsal-ventral or medial-lateral). Finally, I also took additional notes about preservation quality, unique features and suspected juvenile status based on the small size of the premaxilla/maxilla.

In situations where data were missing I used either the letters ‘inc.,’ standing for incomplete or ‘N/A,’ meaning ‘not applicable.’ I used ‘inc.’ to indicate that additional features, such as more alveoli, might exist but cannot be positively identified or the true size of a feature may be larger than indicated but sections were missing or too covered in plaster to determine an exact size. ‘N/A’ was used to indicate that the element simply was not present.

CHAPTER FOUR: DATA ANALYSIS

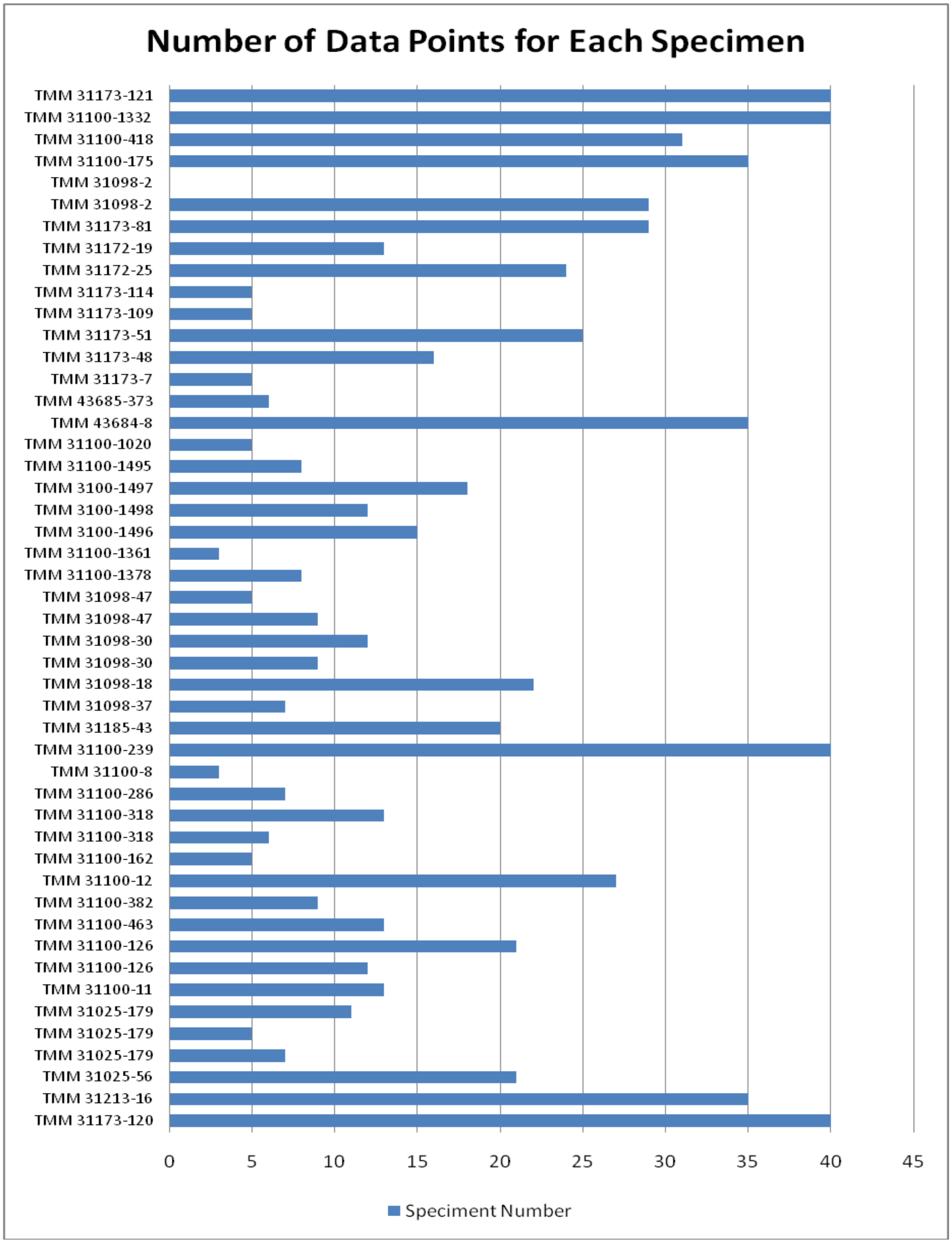
I analyzed all the data and performed statistical analysis using Microsoft Excel. This included calculating the number of specimens that contained relevant data points, minimum and maximum values, averages, totals, and standard deviations. Before conducting any of these statistics I removed data points marked as incomplete or not available. Also, the term ‘at least’ was removed so only the number remained. For example, ‘at least four’ was replaced with ‘four.’ The term ‘at least’ was typically used to refer to elements that had too much matrix or were too crushed to positively identify if any additional data points exist. By removing the term ‘at least’ and just identifying the number this could lead to bias by having the some data be under-represented. For example, a specimen might have five or more alveoli but because of excessive matrix only four could be positively identified. Therefore, only four of the alveoli would be represented in the statistical analysis even though more alveoli actually exist. However, without positive identification indicating that there were more alveoli than could be verified this would also lead to bias through overrepresentation. I attempted to deal with this issue by having a large sample size of specimens.

When two data points were being compared (for example; the length of the right versus left second alveolus) I used a two-tailed paired student t-test with Microsoft Excel software. The t-test was selected because it would determine if the two sets of data were significantly different from each other. In order to perform a two tailed paired t-test only specimens that had data for both features were counted. For example, if the left premaxilla was recorded as 4mm but the right premaxilla was recorded as incomplete both were removed from analysis. In situations when more than two data points were being compared (for example; comparing the length of the second, fourth and fifteenth premaxillary alveoli) I used an ANOVA test or chi-square analysis using StatPac Statistic Calculator Version 4.0 Evaluation Version (Copyright 1997-2011 StatPac, Inc.). The ANOVA was used to determine whether the means between several groups were equal. The chi-square statistic was used to determine whether the distributions of the variables differed from one another. All statistical tests required an alpha-level confidence interval of $\alpha \leq 0.05$ to be considered statistically significant.

CHAPTER FIVE: RESULTS

5a. Number of Data Points for Each Specimen

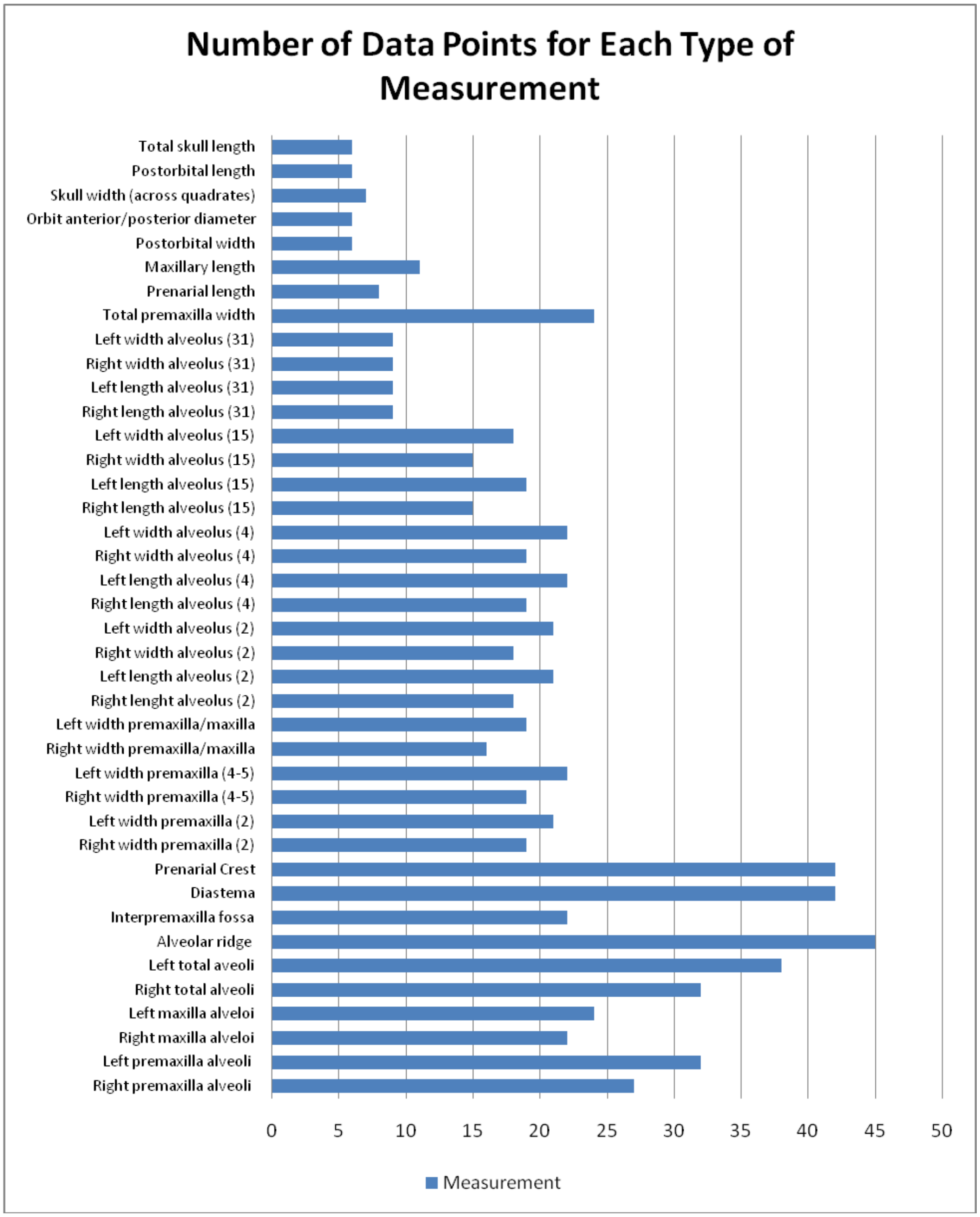
Of the 48 specimens I studied, only four contained recorded information for all 40 possible data points. The minimum number of recorded data points was zero with the next lowest being three and the average around 16. A more detailed breakdown of the number of data points for each specimen is provided in Graph 5a.1.



Graph 5a.1: The maximum number of data points each specimen had recorded.

5b. Frequency of Data Points

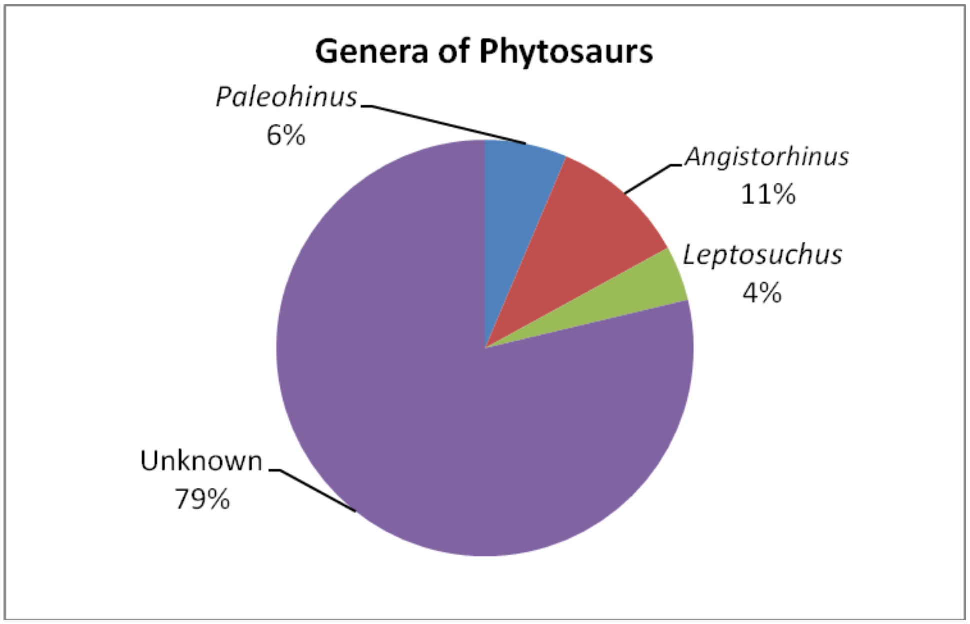
In addition to recording the number of data points per specimen I analyzed which types of measurements were most frequently recorded. The greatest recorded measurement was the alveolar ridge with 45 out of the 48 specimens containing information about that feature. Other frequently recorded data points were the diastema and prenarial crest, total premaxilla width, and the number of alveoli. The least-recorded measurements were all associated with the postorbital. Only six of the specimens had informaiton about the postorbital width, anterior/posterior orbit diameter, postorbital length and total skull length. Only seven specimens had information about the skull width. Measurements of the prenarial length and maxillary length were also infrequent (eight and eleven specimens respecitively). On average each data category had informaiton from about 19 different specimens.

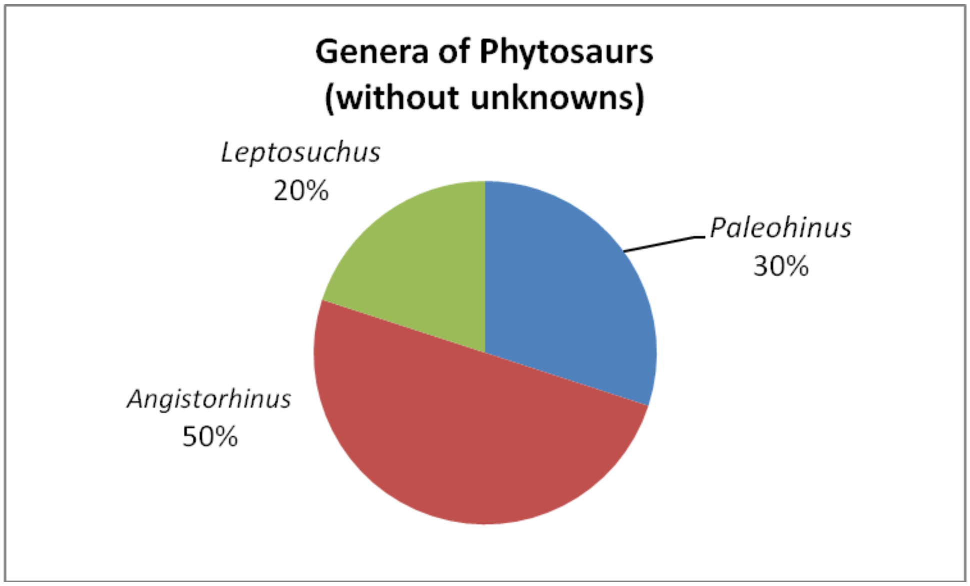


Graph 5b.1: Number of data points for each type of measurement. The number in parenthesis refer to the alveolus that was measured. For example; left width alveolus (4) refers to the width of the fourth alveolus on the left-side element. Left width premaxilla (4-5) refers to the width of the premaxilla between the fourth and fifth alveoli on the left-side element.

5c. Taxon

Few of the specimens used were taxonomically identified. This is probably because many of the fragments were small, isolated, and of elements that don't have obvious diagnostic features. Of the 47 specimens 37 (78.72%) have unknown taxonomic affinity. Of the remaining 10 specimens only three different genera were recorded (*Paleohinus, Angistorhinus,* and *Leptosuchus*). The majority of these (five, or 10.64%) were *Angistorhinus*; three (6.38%) were assigned to the taxon *Paleohinus*, and only two (4.26%) to *Leptosuchus*. One specimen was labeled as Phytosauridae but did not have genus identification so I didn't include it in my statistical analysis of the phytosaur genera.





Graph 5c.1 and 5c.2: Percentages of phytosaur genera with and without unknowns. Chi-square analysis between the three recorded genre (chi-square statistic = 1.4, df = 2, p-value = 0.4966) showed no statistically significant difference between the number of specimen belonging to each genus.

5d. Alveoli Counts

I ran several statistics on the number of alveoli in each specimen to see if there were differences between the right versus left side of the element or between the premaxilla and maxilla. These included comparing the number of right versus left premaxillary alveoli, the number of right versus left maxillary alveoli, the number of left premaxillary versus left maxillary alveoli, the number of right premaxillary versus right maxillary alveoli and the total number of right versus left alveoli.

A synopsis of alveoli count data for all specimens is provided in Table 5d.1; it includes a summary of the p-values obtained from conducting two tailed paired t-test on the right versus left premaxilla, the right versus left maxilla, the left premaxilla versus maxilla, and the right premaxilla versus maxilla. According to the p-values on the table it is reasonable to assume that there is no statistically significant difference between the number of alveoli between the right versus left premaxilla, the right premaxilla versus right maxilla, the right and left maxilla, and the total number of right versus left alveoli in both the premaxillary and maxillary elements within the same specimen. These results were unsurprising given that most data sets had an average difference of zero to three alveoli. Overall, the number of alveoli was consistent among the data sets.

The only data set that did show significance was the left premaxillary versus left maxillary alveoli (p-value = 0.0011; $\alpha < 0.05$). Among the 18 specimens with both left premaxillary and maxillary elements the average number of left premaxillary alveoli was 17 ± 5.86 while the average number of left maxillary alveoli was 11.72 ± 6.03. Therefore, the specimens in this study had a statistically higher number of left premaxillary alveoli as compared to left maxillary alveoli.

	Right Premaxillary Alveoli	Left Premaxillary Alveoli	Right Maxillary Alveoli	Left Maxillary Alveoli	Right Total Alveoli	Left Total Alveoli
Total number of specimens containing element	27	32	22	24	32	38
Minimum number of alveoli per specimen	4	3	1	2	4	3
Maximum number of alveoli per specimen	26	25	27	21	45	43
Total number of alveoli between all specimens	374	472	283	296	653	767
Average number of alveoli	13.85	14.75	12.86	12.33	20.41	20.18
Standard Deviation	6.96	6.84	7.51	5.55	13.58	11.79

Table 5d.1: Synopsis of alveoli count data for the right and left premaxillae and maxillae as well as totals.

	Premaxilla		**Maxilla**		**Right**		**Left**		**Total Alveoli**	
	Right	Left	Right	Left	Premax.	Maxilla	Premax.	Maxilla	Right	Left
Avg.	14.18	14.23	13.33	13.07	17.06	13.53	17.39	11.72	21.21	21.21
SD	7.20	7.15	7.22	5.96	5.77	7.71	5.86	6.03	13.08	12.76
T-Test p-value	0.92		0.85		0.11		0.0011		1.00	

Table 5d.2: T-Test results for alveoli counts between right and left premaxillae and maxillae elements. Only the average number of alveoli between the left premaxilla and maxilla is statistically significant. ‘Avg.’ refers to average, ‘SD’ refers to standard deviation and ‘premax.’ refers to premaxilla.

5e. Alveoli Length and Width

The length and width of premaxillary alveoli two, four, and fifteen were measured in millimeters. A summary of the raw data and statistical analyses is provided in Tables 5e.1, 5e.2, and 5e.3.

	Second Premaxillary Alveolus				Fourth Premaxillary Alveolus				Fifteenth Premaxillary Alveolus			
	Length		Width		Length		Width		Length		Width	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
# of samples	18	21	18	21	19	22	19	22	12	16	12	16
Min. (mm)	4.18	3.27	3.97	3.02	2.19	1.30	1.95	1.69	3.17	3.52	3.01	2.99
Max. (mm)	38.7	22.6	27.8	25.0	15.6	11.7	19.7	15.0	15.6	12.7	19.0	12.7
Avg. (mm)	15.9	12.5	13.1	10.8	6.13	6.37	6.11	6.21	8.27	7.79	9.10	7.12
STDV	9.12	6.94	7.35	6.19	3.33	3.04	4.08	3.12	4.28	2.89	5.35	3.10

Table 5e.1: Length and width measurements of the second, fourth, and fifteenth premaxillary alveoli. 'R.' refers to right, 'L.' refers to left, 'Min.' refers to minimum value, 'Max.' refers to maximum value, 'Avg.' refers to average and 'STDV' refers to standard deviation.

		Length		Width		Right		Left	
		Right	Left	Right	Left	Length	Width	Length	Width
Second Premaxillary Alveolus	**Average (mm)**	17.01	14.84	13.84	12.83	15.94	13.07	12.48	10.79
	Standard Deviation	9.10	6.25	7.44	5.67	9.12	7.35	6.94	6.19
	T-Test p-value	0.14		0.35		0.0023		0.010	
Fourth Premaxillary Alveolus	**Average (mm)**	6.55	6.93	6.64	6.69	6.13	6.11	6.37	6.21
	Standard Deviation	3.46	2.96	4.23	3.41	3.33	4.08	3.04	3.32
	T-Test p-value	0.40		0.92		0.94		0.59	
Fifteenth premaxillary Alveolus	**Average (mm)**	8.63	8.20	8.27	9.10	9.57	7.62	7.79	7.12
	Standard Deviation	4.29	3.25	4.28	5.35	5.35	3.35	2.89	3.10
	T-Test p-value	0.66		0.43		0.056		0.043	

Table 5e.2: T-Test results for average length and width of the second, fourth, and fifteenth premaxillary alveoli on the right versus left side of the specimens. The only tests that were statistically significant were those between the length versus width of the second premaxillary alveolus on the right (p-value = 0.0023) and left side (p-value = 0.010), and the length versus width of the fifteenth premaxillary alveolus on the left side (p-value = 0.046). There were no statistically significant differences on the fourth premaxilla.

	Length		Width	
	Right	Left	Right	Left
ANOVA p-value	0.00	0.008	0.011	0.027

Table 5e.3: ANOVA results for the length and width of the right and left alveoli across the second, fourth, and fifteenth premaxillary alveoli. In all three cases there was a statistically significant difference between the length and the widths of the three different alveoli on both the right and left side.

5f. Width of Premaxilla and Premaxilla/Maxilla Boundary

The right and left premaxilla at three different locations; the second alveolus, between the fourth and fifth alveoli, and at the premaxilla/maxilla boundary were recorded in millimeters. These results are summarized in Table 5f.1.

	Premaxilla width at the second alveolus		Premaxilla width between the fourth-fifth alveoli		Width at the premaxilla/maxilla boundary	
	Right	Left	Right	Left	Right	Left
# of specimens	18	21	18	20	16	18
Minimum	8.02	7.60	4.58	4.32	14.99	12.00
Maximum	58.55	61.75	45.25	45.36	49.15	46.25
Average	29.41	26.12	19.88	18.79	28.70	23.73
Standard Deviation	15.44	15.78	11.02	10.70	9.75	10.62

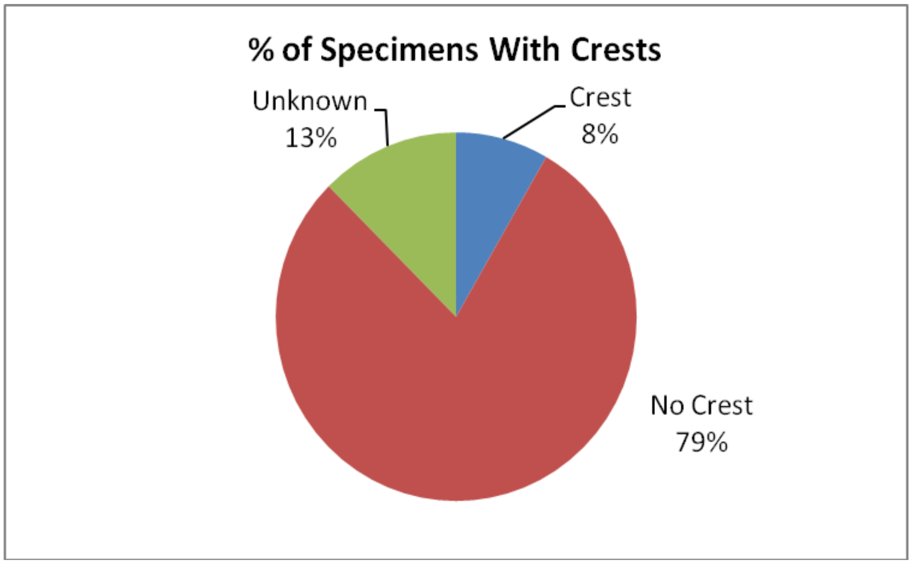
Table 5f.1: Width measurements and statistics of the right and left premaxilla in millimeters at the second alveolus, between the fourth and fifth alveoli, and at the premaxilla and maxilla boundary.

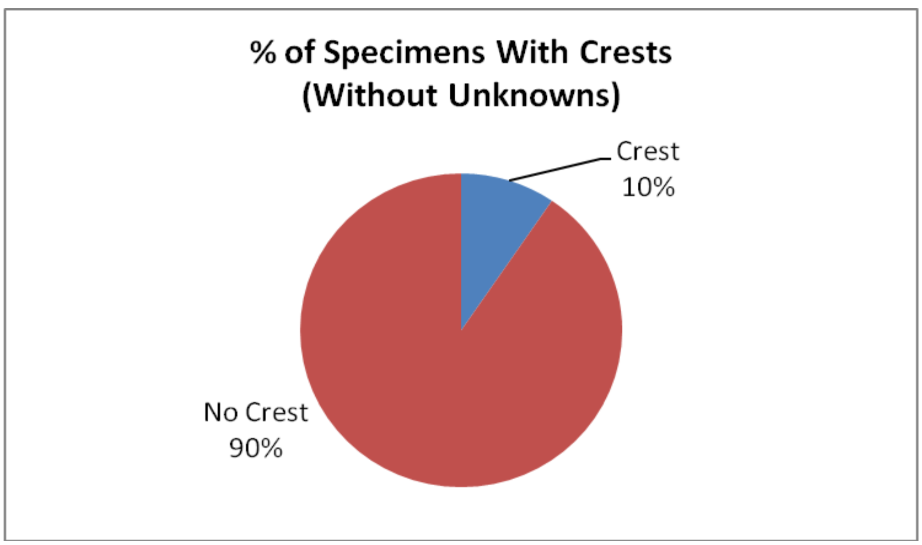
In addition to collecting data on the width of the premaxilla as a whole I also compared individual data points. For example, the width of the right premaxilla at the second alveolus was compared to the width of the left premaxilla at the same location. I conducted a two-tailed paired t-test to compare the width of the right versus left premaxilla at the second alveolus. The right premaxilla had an average measurement of 15.76 ± 15.76 mm while the left was 31.04 ± 14.91 mm. The t-test (p-value = 0.8815) showed no statistically significant difference between the width of the right and left premaxilla at the location of the second alveolus. Similar results were found between the width of the right and left premaxilla between the fourth and fifth alveoli (p-value = 0.8775) and between the right and left premaxilla/maxilla boundary (p-value = 0.2310).

I conducted another ANOVA to compare all three measurements on the right side of the premaxilla and maxilla. It showed no statistical significance between the width of the premaxilla at the second alveolus, fourth-fifth alveoli, and premaxilla/maxilla boundary (p-value = 0.14). The same result of no statistical significance also was reported when an ANOVA was conducted to compare the widths on the left side of the premaxilla (p-value = 0.23).

5g. Prenarial crest

Of the 48 specimens that were part of this study, four (8.33%) contained notable prenarial crests whereas the vast majority (79.17%) did not. This was even more evident when the six unknown samples were removed. Then 9.52% of the samples had prenarial crests whereas 90.48% did not. Of the three samples pre-labeled as juveniles, none had prenarial crests. These data are summarized in Graphs 5g.1 and 5g.2.





Graph 5g.1 and 5g.2: Percentage of elements with prenarial crests. The majority of samples (79%) did not have prenarial crests.

In addition to counting the number of juveniles with prenarial crests I also compared the presence of prenarial crests with total prenarial size. Of the three specimens with recorded prenarial lengths of less than 500mm, none contained prenarial crests. Of the five specimens with recorded prenarial lengths greater than 500mm, three (60.00%)

had prenarial crests whereas two (40.00%) did not. Of the two specimens with recorded prenarial lengths greater than 600mm both had prenarial crests. A two-tailed paired student t-test was performed on each of these data points showing no statistically significant difference between the prenarial length and the presence or absence of a prenarial crest (see Table 5g.3).

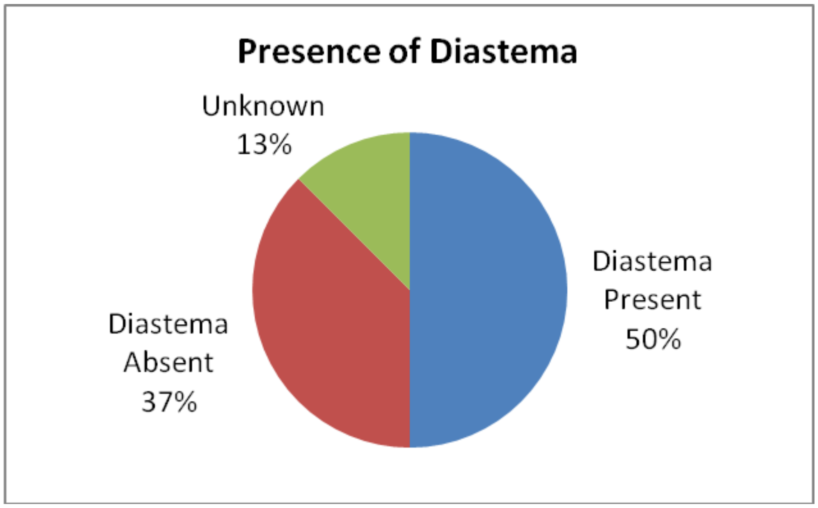
	Prenarial length < 500mm	**Prenarial length > 500mm**	**Prenarial length > 600mm**
t-statistic	2.449	0.439	2.000
Degrees of freedom	4	3	2
p-value	0.0705	0.6907	0.1835

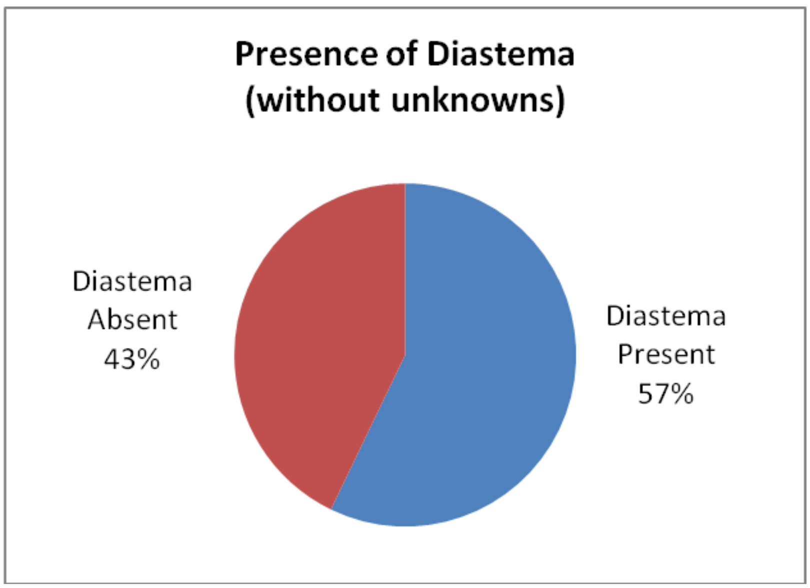
Table 5g.3: T-Test results on prenarial length compared to the presence and absence of prenarial crests. In all three cases there is no statistically significant difference between the size of the prenarial length and presence and absence of a prenarial crest.

I also compared the presence of a prenarial crest with the total skull length. Three samples had a recorded total skull length of less than 900mm. Another three samples had a recorded total skull length greater than 900mm. Unfortunately, two of the samples were unclear as to whether or not the prenarial crest was present. Because of the limited number of data points, no statistical analysis could be run to test whether the total skull length impacts the presence or absence of a prenarial crest.

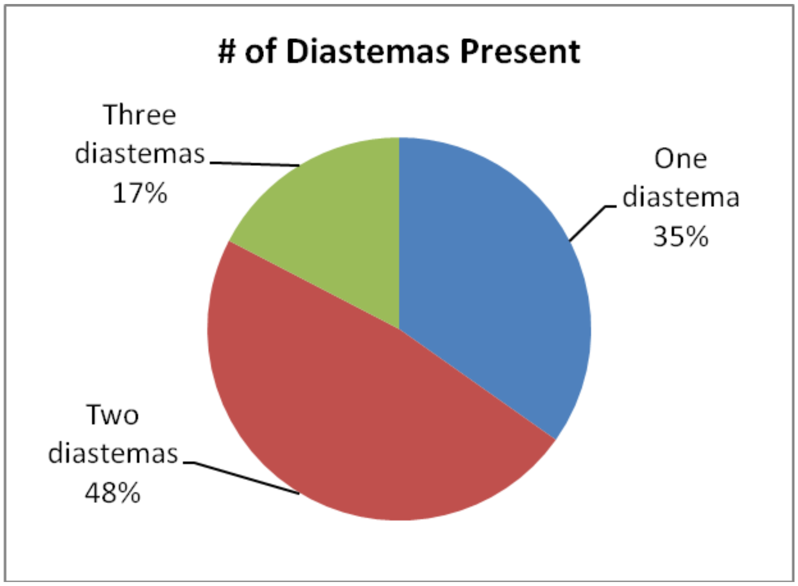
5h. Diastema

Over half the samples in this study had at least one diastema present (Graph 5h.1 and 5h.2). I also recorded the number of diastemas per specimen (Graph 5h.3). Of the 23 specimens with diastema, eight (34.78%) contained only one, 11 (47.83%) contained two, and four (17.39%) contained three. There were no specimens in this study that had more than three diastemas recorded.



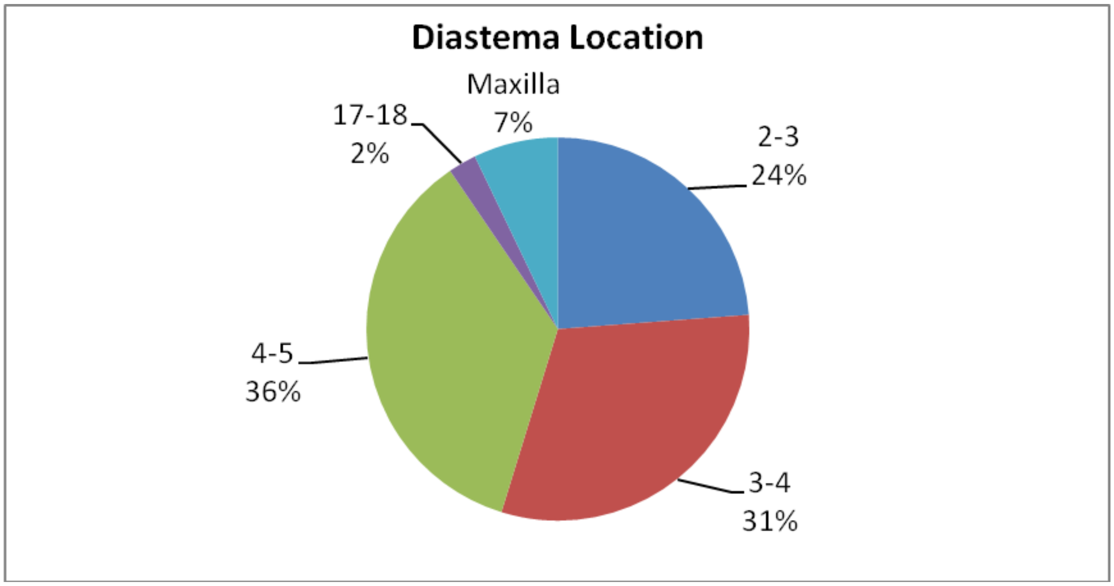


Graph 5h.1 and 5h.2: Percentage of samples with at least one diastema present (with and without unknowns).



Graph 5h.3: Percentages of specimens with one, two, or three diastemas. Even though the major of samples had at least two diastemas a chi-square analysis (chi-square statistic = 7.492, df = 20, p-value = 0.9947) showed no statistically significant difference between the number of diastemas present in each specimen.

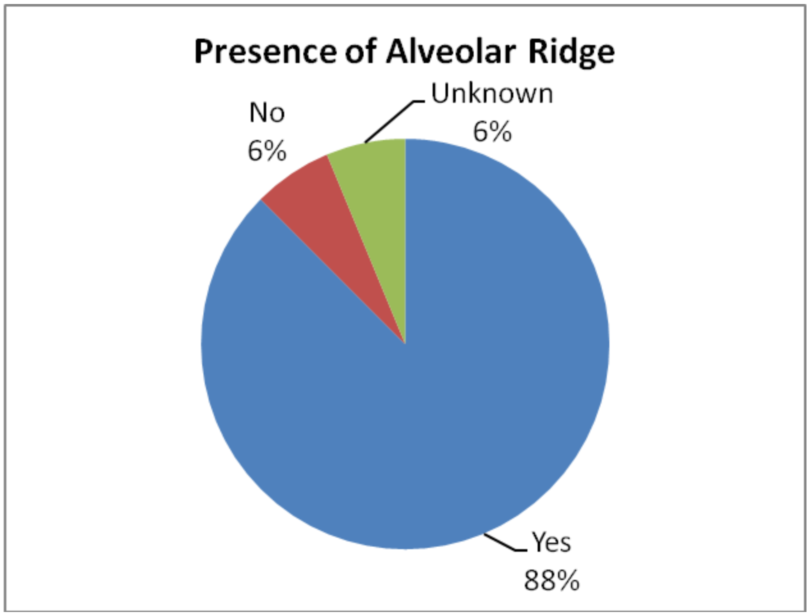
Although the presence of 42 different diastemas were recorded, the vast majority seemed to be found at the anterior portion of the premaxilla. Most of these were between the second and third premaxillary alveoli, the third and fourth premaxillary alveoli, and the fourth and fifth premaxillary alveoli. Only one was between the seventeenth-eighteenth premaxillary alveoli and only three were located in the maxilla. Although the vast majority of diastemas diastema were in the premaxilla and towards the anterior end a chi-square anlaysis and t-test showed no statistically significant difference in diastema location (Graph 5h.4)

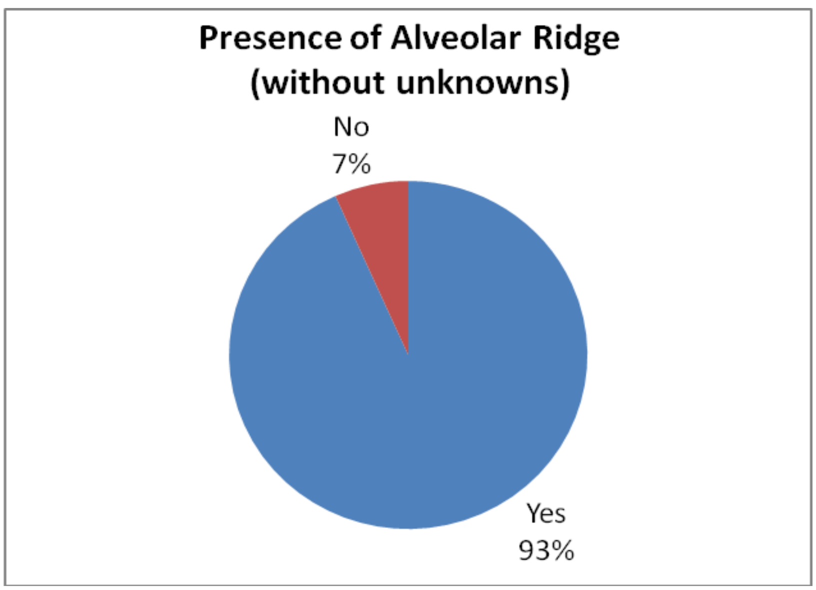


Graph 5h.4: Percentages of diastema found between the second-third premaxillary alveoli (2-3), third-fourth premaxillary alveoli (3-4), fourth-fifth premaxillary alveoli (4-5), seventeenth-eighteenth premaxillary alveoli (17-18), and maxilla. Chi-square analysis (chi-square statistic= 25.424, df = 70, p-value = 1.0000) showed no statistically significant difference in diastema location. A two-tailed student t-test preformed on the number of diastemas in the premaxilla versus maxilla also showed no significance (p-value = 0.062).

5i. Alveolar Ridge

For each specimen I noted the presence or absence of an alveolar ridge (Graph 5i.1 and 5i.2). Alveolar ridges are palatal ridges (Case and White, 1934). The alveolar ridges are visible in the lateral view for all phytosaurs except pseudopalatines (Stocker, 2010). In some taxa the alveolar ridge is more ventrally located than the lateral edges of the premaxilla and maxilla. In others it is visible below the lateral edge of the skull (Stocker, 2010).





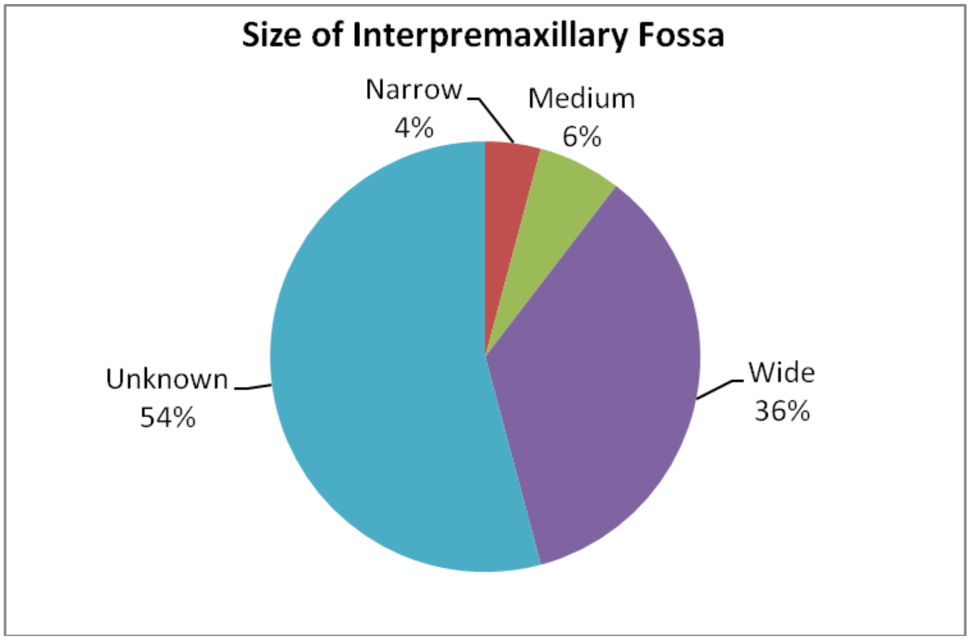
Graph 5i.1 and 5i.2: Percentages of specimens with alveolar ridge (with and without unknowns). The vast majority of specimens did contain an alveolar ridge. A t-test (t-statistic = 4.393, df = 43, p-value = 0.0001) showed a statistically significant difference in the presence of alveolar ridges among the samples.

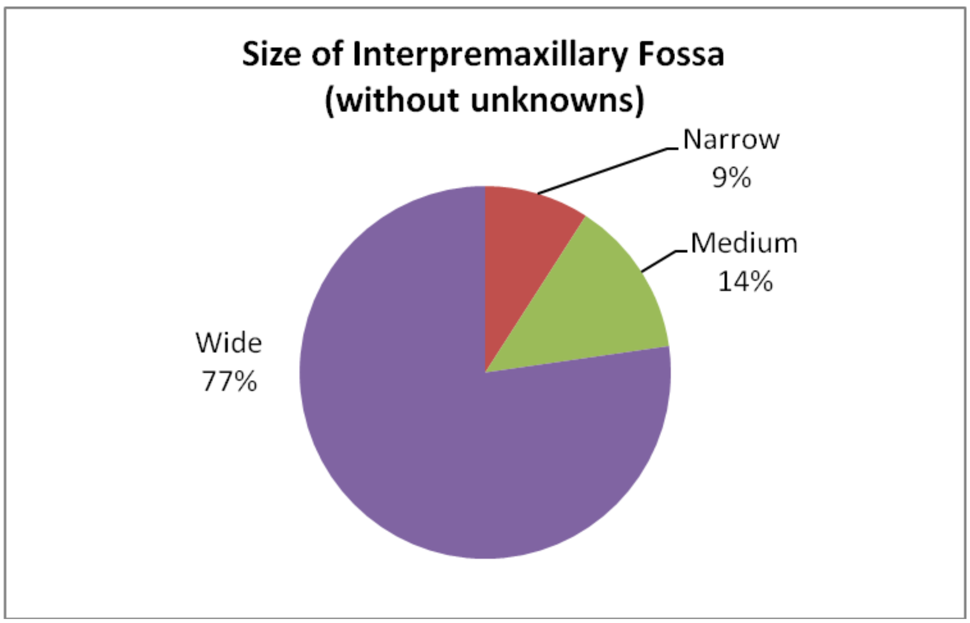
In addition to noting the presence or absence of the alveolar ridge I also noted the size of the alveolar ridge. Small meant generally that the ridge did not extend beyond ten millimeters. Of the 48 total samples, 16 (33.33%) were labeled as small whereas 26 (67.67%) were not. Out of the 42 samples that had an alveolar ridge 38.10% were labeled as small while 61.90% were not. I conducted a paired two-tailed student t-test on the data to test for significance (t-statistic = 2.105, df = 40, p-value = 0.0416). The test showed that there was a statistically significant difference in the number of samples with and without small alveolar ridges.

5j. Interpremaxillary Fossa

For each specimen I recorded the presence or absence of the interpremaxillary fossa. The interpremaxillary fossa is the portion of the premaxillae surrounding the interpremaxillary suture (medial to the alveolar ridges in phytosaurs; Stocker, 2010). I also measured whether the fossa is narrow, medium or wide. Narrow was designated as just a couple millimeters across, wide was designated as several centimeters across, and medium was by discretion in between those values.

Presence or absence of an interpremaxillary fossa could not be determined for 54.17% of the specimens. All the remaining samples have an interpremaxillary fossa. Amongst these known samples the vast majority (17 or 35.42%) have wide interpremaxillary fossa, three (6.25%) have medium, and two (4.17%) have narrow. When the unknown samples were removed the number of specimens with wide interpremaxillary fossa increased to 77.27% with only 13.64% having medium, and 9.0% being recorded as narrow (Graph 5j.1 and 5j.2). In both cases there was no statistically significant difference between the sizes of the interpremaxillary fossa.

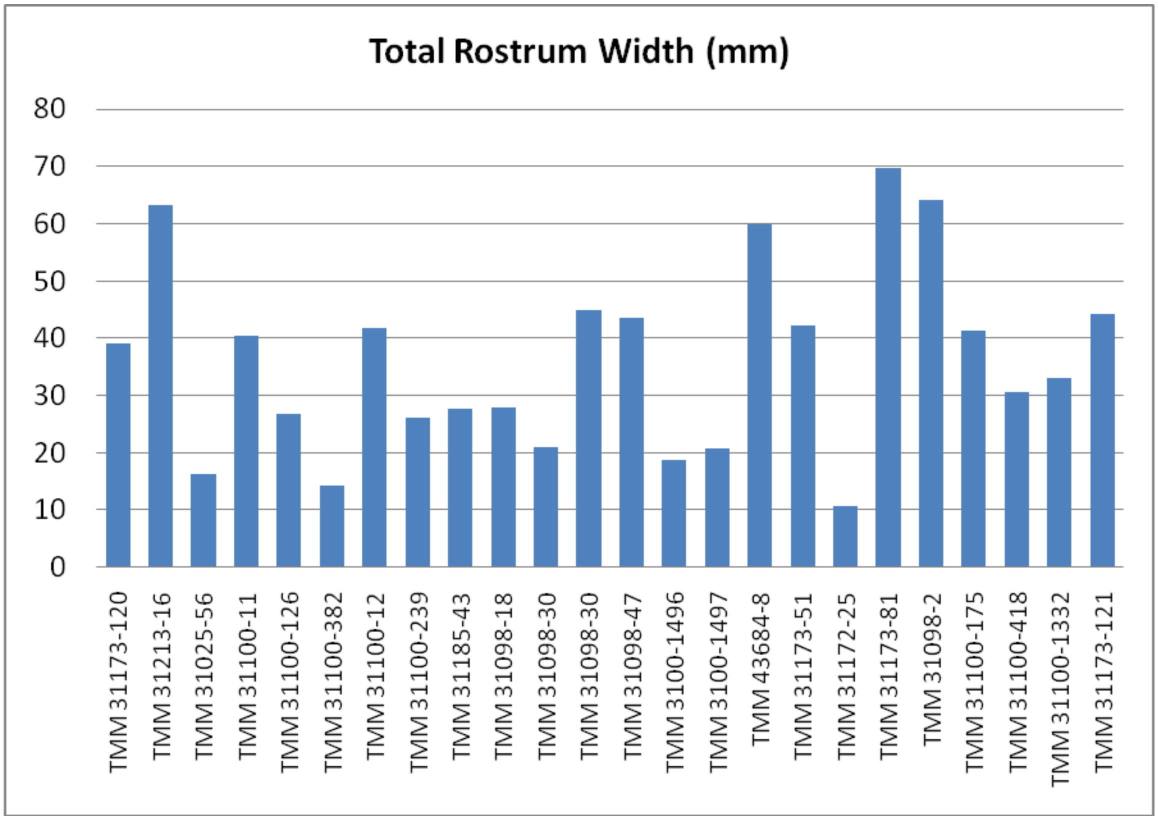




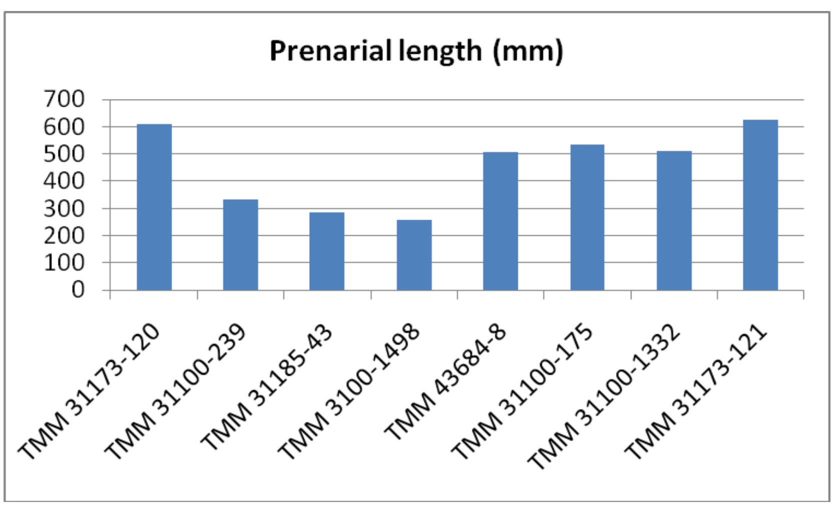
Graph 5j.1 and 5j.2: Percentage of specimens with narrow, medium, and wide interpremaxillary fossa (with and without unknowns). Chi-square analysis (chi-square statistic = 30.528, df = 75, p-value = 1.000) showed no statistically significant difference between the size of the interpremaxillary fossa. Another chi-square analysis was done excluding the unknowns (chi-square statistic = 13.516, df = 32, p-value = 0.9969) but the results also showed no statistical significance because the sample size was too small.

5k. Skull Measurement

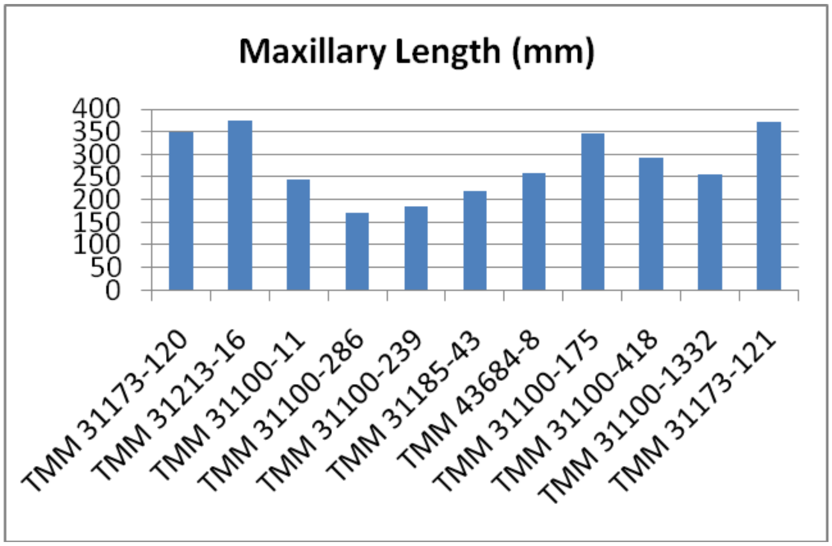
I recorded data on the following skull measurement: total rostrum width (Graph 5k.1), prenarial length (Graph 5k.2), maxillary length (Graph 5k.3), postorbital width (Graph 5k.4), orbit anterior/posterior diameter (Graph 5k.5), skull width across the quadrates (Graph 5k.6), postorbital length (Graph 5k.7), and total skull length (Graph 5k.8). A summary of all the data can be found in Table 5k.9. The purpose of recording these skull measurements was to gather addition data on the size and morphology of the phytosaur specimens. In addition, these data were used to compare the overall size of the specimen to the presence, absence, or size of other characteristics. For example, earlier I compared skull size the presence or absence of prenarial crests. These features also were used as morphological indicators of ontogenetic maturity by researchers such as Fara and Hungerbühler (2000).



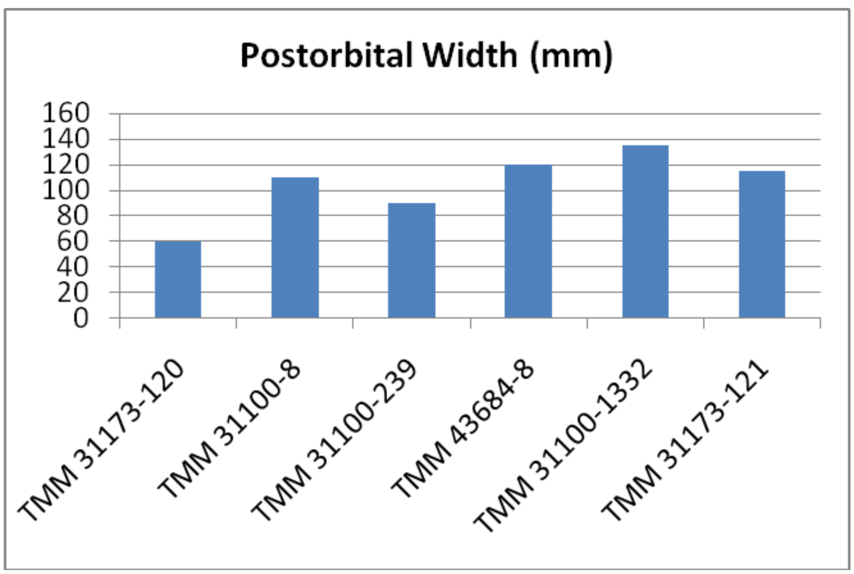
Graph 5k.1: Total rostrum width (millimeters) for each specimen. Widths ranged from 10.65-69.63mm and averaged 36.17 ± 16.40mm.



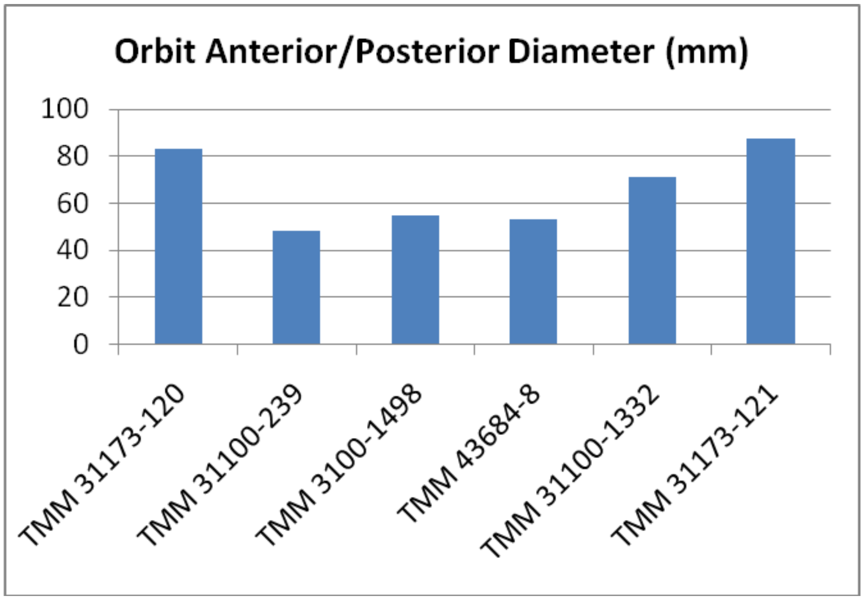
Graph 5k.2: Prenarial length (millimeters) for each specimen. Lengths ranged from 256-624mm and averaged 456.86 ± 145.52mm.



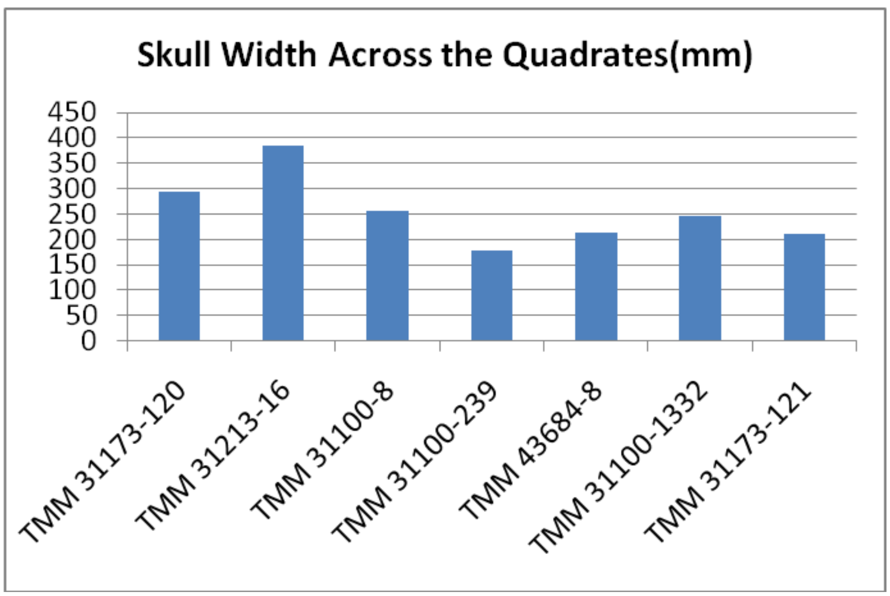
Graph 5k.3: Total maxillary length (millimeters) for each specimen. Lengths ranged from 170.40-374.00mm and averaged 278.71 ± 73.01mm.



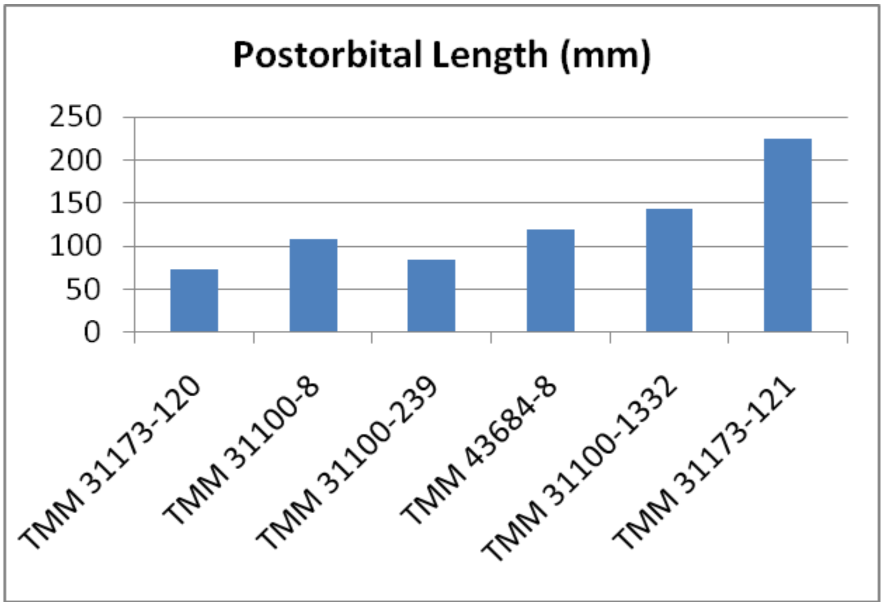
Graph 5k.4: Total postorbital width (millimeters) for each specimen. Widths ranged from 59.50-134.90mm and averaged 104.88 ± 26.60mm.



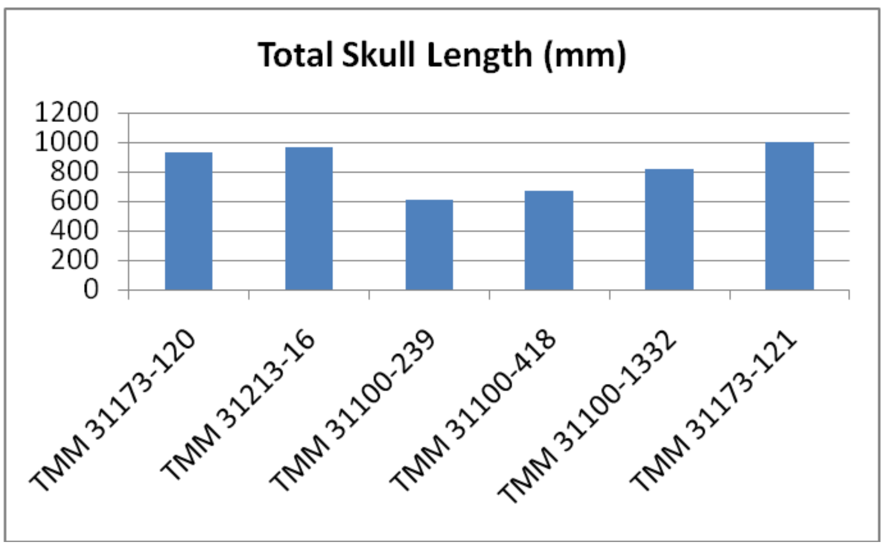
Graph 5k.5: Anterior/Posterior diameter of the orbits (millimeters) for each specimen. Diameters ranged from 48.00-87.50mm and averaged 66.25 ± 16.67mm.



Graph 5k.6: Skull width across the quadrates (millimeters) for each specimen. Widths ranged from 177-385mm and averaged 254.93 ± 68.41mm.



Graph 5k.7: Postorbital length (millimeters) for each specimen. Lengths ranged from 72.5-224mm and averaged 125.33 ± 54.43mm.



Graph 5k.8: Total skull length (millimeters) for each specimen. Lengths ranged from 612.00-998.70mm and averaged 832.28 ± 161.50mm.

	Total Rostrum Width	Prenarial Length	Maxillary Length	Postorbital Width	Orbit Anterior/ Posterior Diameter	Skull Width Across the Quadrates	Postorbital Length	Total Skull Length
Total	24	8	11	6	6	7	6	6
Min.	10.65	256.00	170.40	59.50	48.00	177.00	14.30	612.00
Max.	69.63	624.00	374.00	134.90	87.50	385.00	224.00	998.70
Avg.	36.170	456.86	278.72	104.88	66.25	254.93	103.88	832.28
STDV	16.40	145.52	73.00	26.60	16.67	68.41	69.38	161.50

Table 5k.9: Synopsis of skull measurements in millimeters. ‘Min.’ refers to the minimum value, ‘max.’ refers to the maximum value, ‘avg.’ refers to average value, and ‘STDV’ refers to standard deviation.

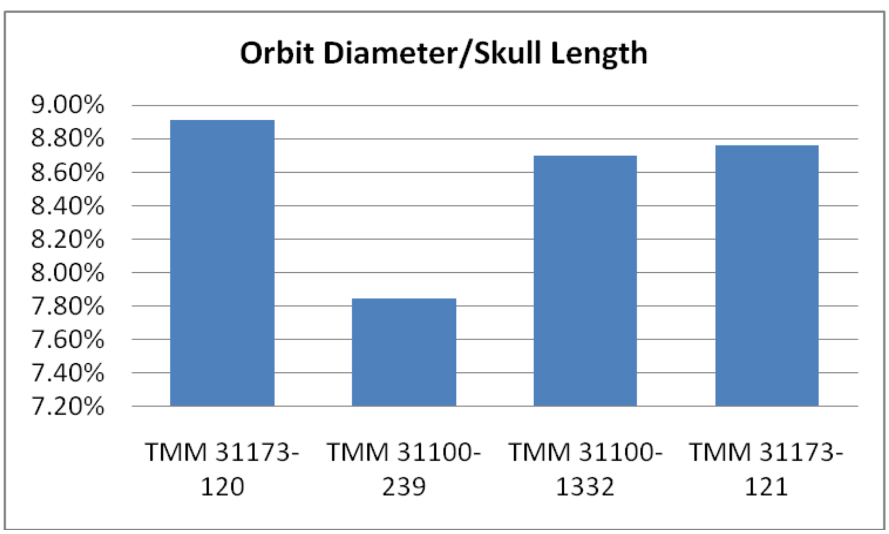
5l. Comparison of my results to those of Fara and Hungerbühler (2000)

In order to study if the ratios of skull measurements statistically differ between adults and presumed juveniles, other authors have compared the prenarial length, skull length, prenarial length/skull length, skull length/snout length, and snout length/skull width of phytosaur specimens (Fara and Hungerbühler, 2000). One hypothesis is that the ratio between skull features would be exaggerated in the juvenile population (Fara and Hungerbühler, 2000). In this study I compared the prenarial length, skull length, and prenarial length/skull length of the measurements I obtained to those published by Fara and Hungerbühler (2000). Unfortunately, the skull length/snout length, and snout length/skull width could not be compared because I have no snout length or width measurements.

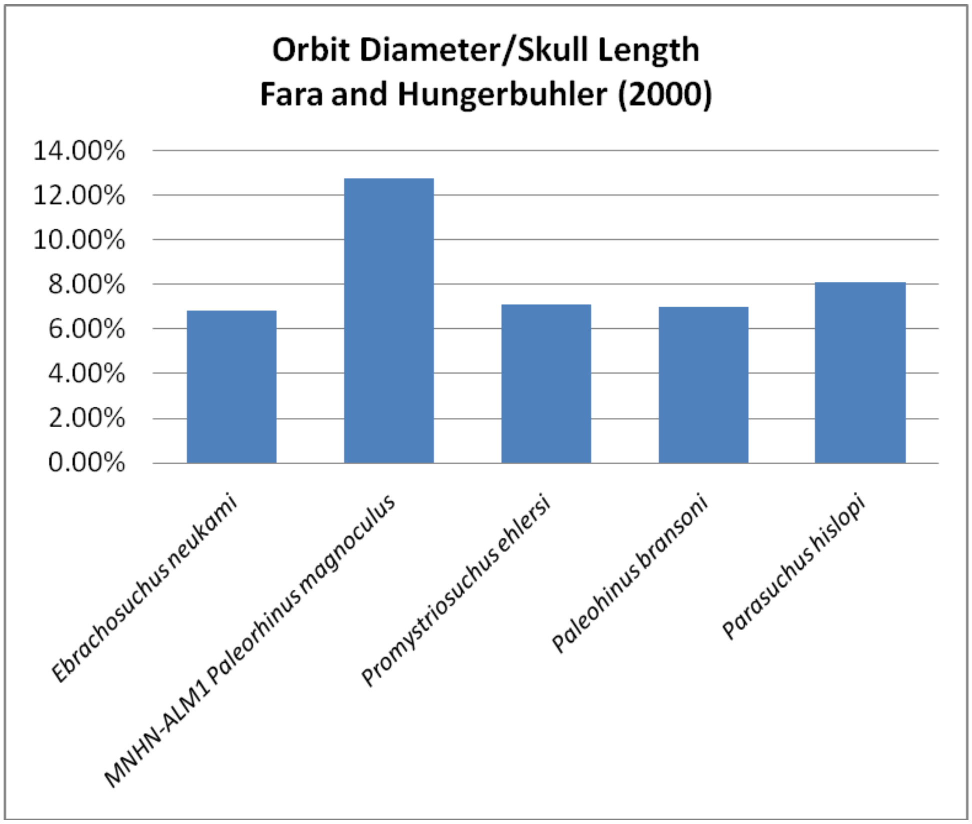
Specimens interpreted as juveniles had orbit diameter/skull length ratios of above 12% and adults had ratios below 9% (Fara and Hungerbühler, 2000). Given these parameters all four specimens in this study (TMM 31173-120, TMM 31100-239, TMM 31100-1332, and TMM 31173-121) would not be considered juveniles based on their orbit diameter/skull length measurements (Table 5l.1, Graph 5l.2, and Graph 5l.3).

Specimen	Orbit Diameter/Skull Length	Specimen (Fara and Hungerbühler, 2000)	Orbit Diameter/Skull Length (Fara and Hungerbühler, 2000)
TMM 31173-120	8.91%	***Ebrachosuchus neukami***	6.85%
TMM 31185-43	7.84%	**MNHN-ALM1 *Paleorhinus magnoculus***	12.76%
TMM 31100-1332	8.70%	***Promystriosuchus ehlersi***	7.12%
TMM 31173-121	8.76%	***Paleohinus bransoni***	6.97%
		Parasuchus hislopi	8.12%

Table 4m.1: Comparison of orbit diameter/skull length ratios between specimens in this study to those published by Fara and Hungerbühler (2000). Based on these results, none of the specimens in this study would be considered juveniles.



Graph 5l.2: Orbit diameter/skull length measurements.

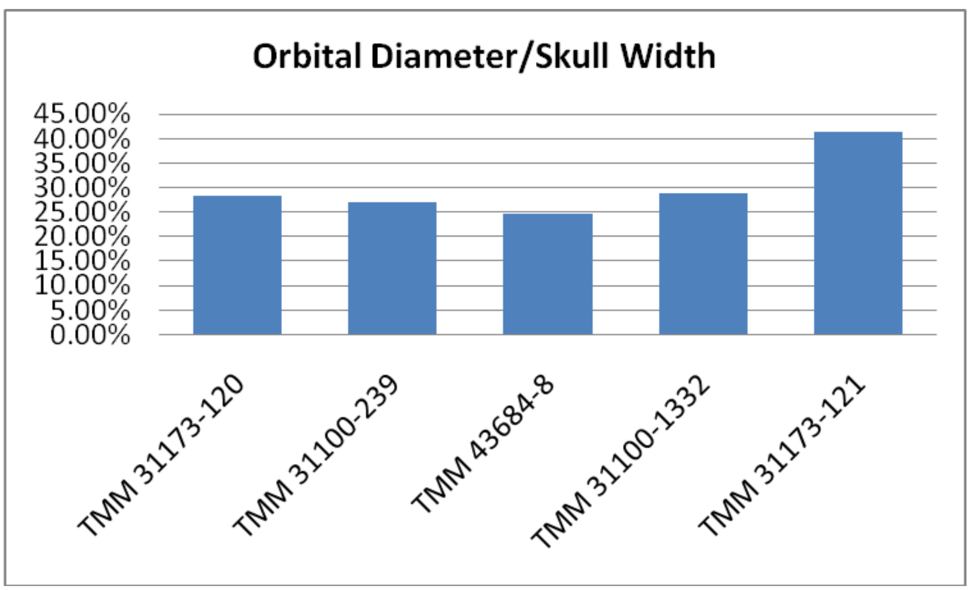


Graph 5l.3: Orbit diameter/skull length measurements published by Fara and Hungerbühler (2000).

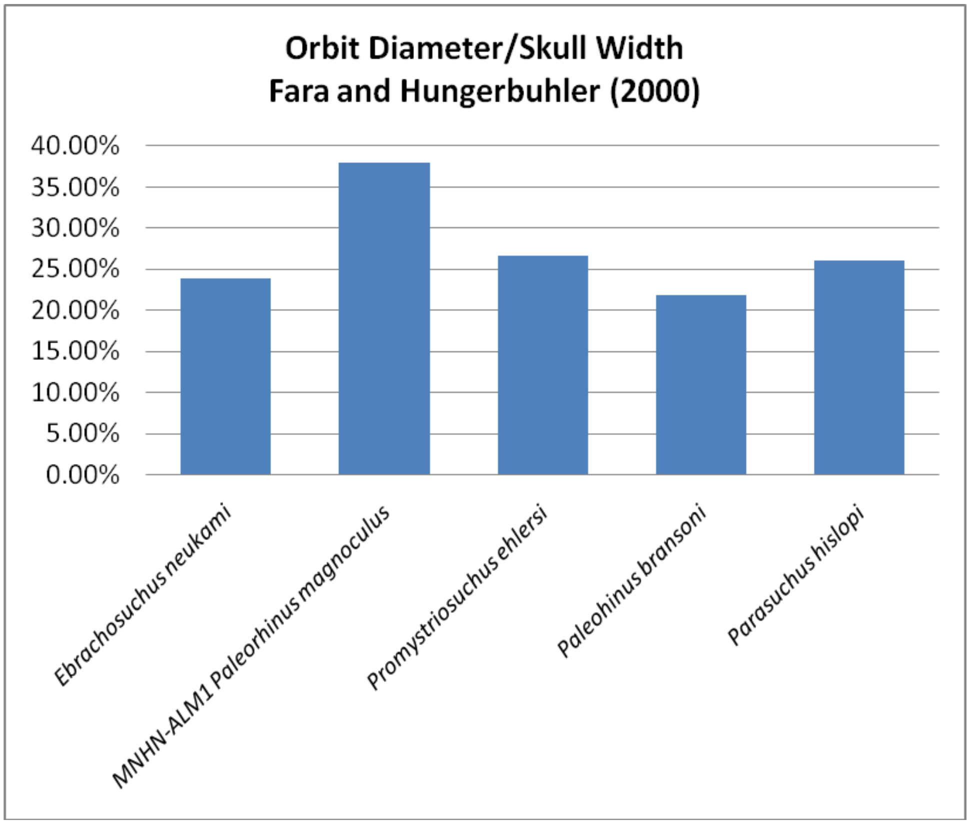
Similarly, the presumed juveniles had an orbit diameter/skull width ratio of above 35% while adults were in the 20% range (Fara and Hungerbühler, 2000). Applying those criteria to my samples, the specimens TMM 31173-120, TMM 31100-239, TMM 43684-8, and TMM 31100-1332 would be considered adults. TMM 31173-121, however, whose orbit diameter/skull width was 41.27% would be considered a juvenile (Table 5l.4, Graph 5l.5, and Graph 5l.6).

Specimen	Orbit Diameter/Skull Width	Specimen (Fara and Hungerbühler, 2000)	Orbit Diameter/Skull Width (Fara and Hungerbühler, 2000)
TMM 31173-120	28.28%	***Ebrachosuchus neukami***	23.90%
TMM 31100-239	27.12%	**MNHN-ALM1 *Paleorhinus magnoculus***	37.99%
TMM 43684-8	24.77%	***Promystriosuchus ehlersi***	26.56%
TMM 31100-1332	28.86%	***Paleohinus bransoni***	21.77%
TMM 31173-121	41.27%	***Parasuchus hislopi***	26.10%

Table 5l.4: Comparison of orbit diameter/skull width ratios between specimens in this study to those published by Fara and Hungerbühler (2000). Based on these results none of the specimens in this study would be considered juveniles except TMM 31173-121.



Graph 5l.5: Orbit diameter/skull width measurements.

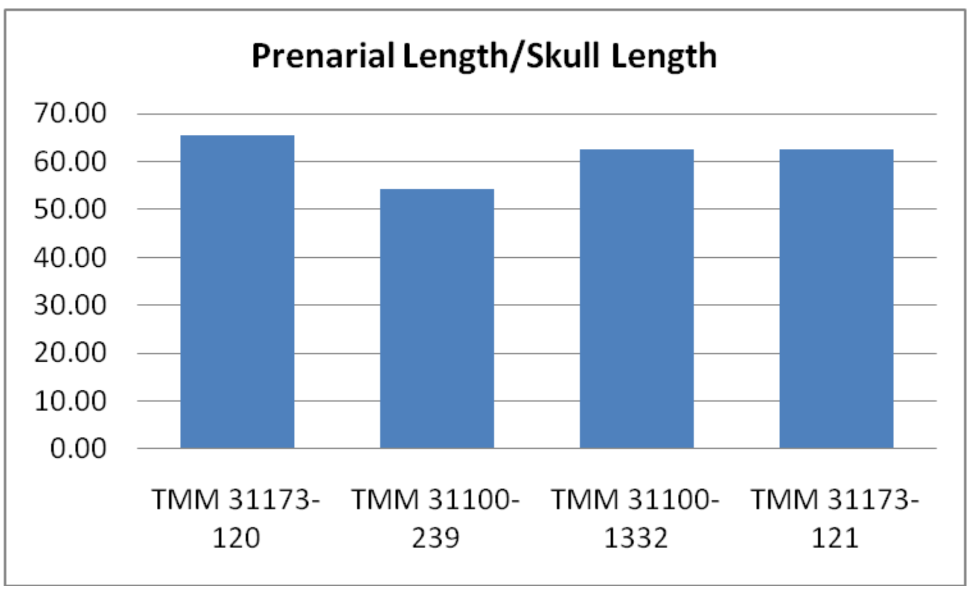


Graph 5l.6: Orbit diameter/skull width measurements published by Fara and Hungerbühler (2000).

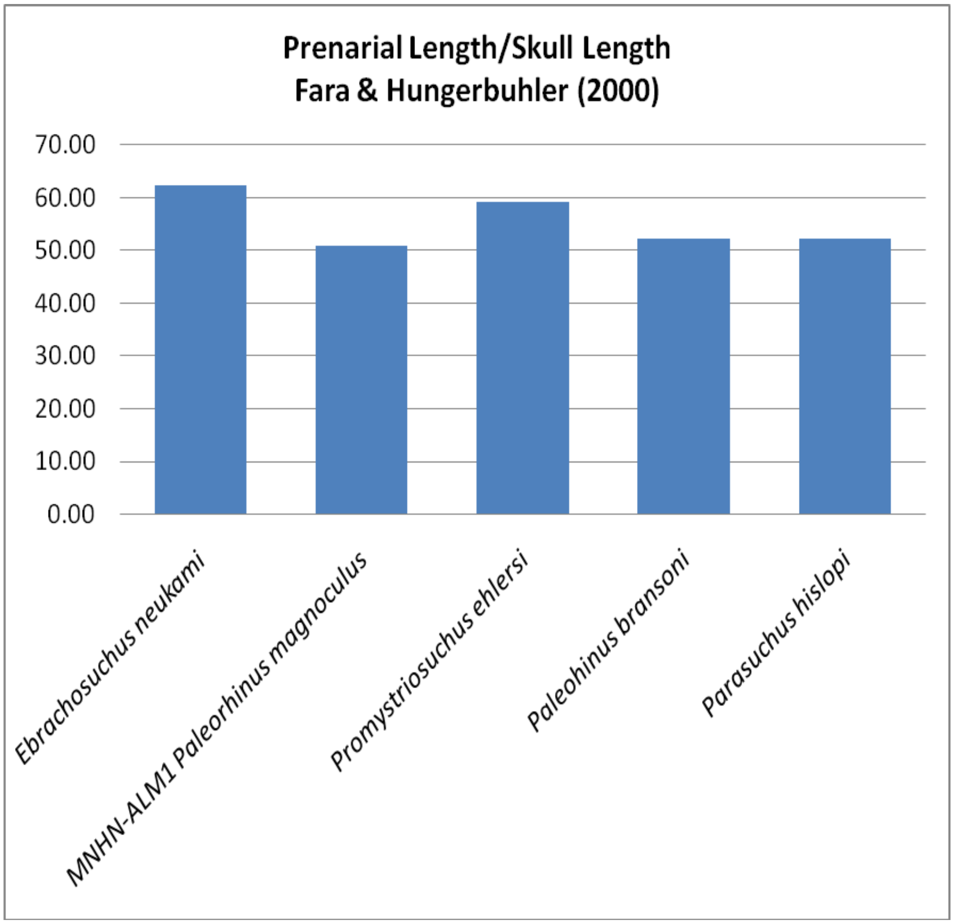
Unlike the previous two measurements, for which the suspected juvenile's features were in a higher ratio than the adults, for prenarial length/skull length the ratio is actually smaller (less than or equal to 51% for juveniles, greater than or equal to 52% for adults). According to these results none of the specimens from my study (TMM 31173-120, TMM 31100-239, TMM 31100-1332, and TMM 31173-121) would be juveniles. See Table 5l.7, Graph 5l.8, and Graph 5l.9.

Specimen	Prenarial Length/Skull Length	Specimen (Fara and Hungerbühler, 2000)	Prenarial Length/Skull Length (Fara and Hungerbühler, 2000)
TMM 31173-120	65.49%	***Ebrachosuchus neukami***	62.28%
TMM 31100-239	54.25%	**MNHN-ALM1** ***Paleorhinus magnoculus***	50.91%
TMM 31100-1332	62.62%	***Promystriosuchus ehlersi***	59.08%
TMM 31173-121	62.48%	***Paleohinus bransoni***	52.13%
		Parasuchus hislopi	52.14%

Table 5l.7: Comparison of prenarial length/skull length ratios between specimens in this study to those published by Fara and Hungerbühler (2000). Based on these results none of the specimens in this study would be considered juveniles.



Graph 5l.8: Prenarial length/skull length measurements.



Graph 5l.9: Prenarial length/skull length measurements published by Fara and Hungerbühler (2000).

CHAPTER SIX: DISCUSSION AND CONCLUSION

6a. Findings

Phytosaurs have been well studied for years but few researchers have made a comprehensive analysis of ontogenetic change in the morphology of the premaxilla and maxilla. I asked the question, can the length, width and number of alveoli give any information about the ontogeny of phytosaur specimens? I measured 40 different data points collected on 48 different specimens to try to obtain as much information as possible on the features of the phytosaur premaxilla and maxilla (as well as some postnarial features such as skull length and orbit diameter). After analyzing all these data points I then used the work of Fara and Hungerbühler (2000) as a foundation to try to determine approximate ontogenetic age of these specimens. While not all the findings in this study are novel there are some that provide insight into patterns and relationships that exist within the phytosaurs dentition.

The first pattern I noticed is the number of premaxillae and maxillae in the collection. Only nine of the 48 specimens have the right and left premaxilla and the right and left maxilla all catalogued under the same specimen number. It is more common to find just the isolated premaxillae or maxillae or elements only on the right or left side. This is because many of the specimens in this collection are not complete skulls but rather only fragments.

Premaxillae are 1.38 times more common than maxillae. This could be because of sampling bias towards premaxillae. Alternatively, there may be fewer maxillae accessible for measurement because of factors such as too much matrix covering the bone or too much crushing to obtain useful information about the element. Left side elements are about 1.57 times more common than right side elements. Given that there is no obvious reason why left side elements would appear more in the fossil record than right side elements I can only assume this is due to random events. However, if these same patterns exist in other collections it would suggest that researchers have a sample bias towards premaxilla and left-side elements.

Unlike the previous measurement, my results show that there is no statistically significant difference between the number of right versus left alveoli or the number of premaxillary versus maxillary alveoli. The one exception was the number of left premaxillary versus left maxillary alveoli. On average there were approximately five more alveoli in the left premaxilla compared to the left maxilla.

It is suprising that this pattern is found only on the left side and not also on the right. The premaxilla is longer than the maxilla in phytosaurs (Chatterjee, 1978) and therefore there should be more alveoli in the premaxilla than the maxilla on both sides of the element. This is supported by my results that there is no statistically significant difference between the number of left and right premaxilla or left and right maxilla. The fact that there were less right side elemnts may explain the lack of statisitical evidence to show there are more premaxillary alveoli than maxillary alveoli on the right side. The sample size may have been too small to detect a statistically significant difference in the number of right premaxillary and maxillary alveoli.

The cross-section of alveoli and rostrum widths that I studied in more detail supported the results reported by Hungerbühler (2000). Like in his study I found the shapes of the alveoli to be of different sizes and, therefore, heterodont throughout the premaxilla (ANOVA analysis, p-value = 0.001). The second premaxilla alveolus from the anterior (located at the terminal rosette) contains alveoli that are larger (average size = 12.96mm ± 7.49mm) as well as longer than they are wide. This makes sense given that the second alveolus is located at one of the widest parts of the premaxilla (average width = 27.64mm ± 15.51mm). Having such a wide area would allow for alveoli to be larger. Also, the larger alveoli would support the hypothesis that phytosaurs were carnivorous predators (Chatterjee, 1978) with enlarged 'fang-like' anterior alveoli for grasping prey (Hungerbühler, 2000).

The fourth alveolus (located at the constriction of the rostrum) has smaller alveoli (average size = 6.21mm ± 3.38mm) with no statistically significant difference between length and width. This makes sense as well given that my results show the location between the fourth and fifth alveoli is one of the narrower regions of the premaxilla (average width = 19.31mm ± 10.72mm). These results confirm data reported by Hungerbühler (2000) findings that the alveoli of the anterior premaxilla are conical and unspecialized.

Finally, the size of the fifteenth alveolus was in between that of the second and the fourth (average size = 7.98mm ± 3.85mm). Again, this follows with the pattern that the width of the premaxilla near premaxilla/maxilla suture (average width = 26.07mm ± 10.37mm) is wider than the area between the fourth and fifth alveoli but narrower than at the second alveolus. In addition, the fifteenth alveolus on the left side is statistically longer than it is wide. These results correspond with data reported by Hungerbühler

(2000) that posterior premaxilla alveoli are high, D-shaped, and bicarinate. I am not sure why this pattern of the fifteenth alveolus being longer than it is wide only exist on the left side of the premaxilla but I again suspect the answer may have more to do with the smaller right-side sample size than with an actual difference between right and left premaxillary alveoli.

It appears the width size of the premaxilla has an impact on size of alveoli. The general trend is the wider the premaxilla area the larger the alveoli. Evolutionarily this direct relationship is probably the result of jaw and tooth specialization to aid with capturing and processing prey. Presumably, the anterior-most ‘fang-like’ teeth were used to stab smaller prey, the stronger posterior premaxillary teeth were used to grasp and kill larger prey, and the trenchant maxillary teeth were used for dismemberment (Chatterjee, 1978 and Hungerbühler, 2000). In *Alligator mississippiensis* (an extant archosaurs) head, jaw, and alveoli shape and size are directly linked to bite force and the capacity to capture and handle different prey (Erickson et al., 2003).

Prenarial crests were a rare find in this study with only 8.33% of the samples containing notable crests. It has been hypothesized that prenarial crests are only present on adult phytosaurs (Camp 1930; Ballew, 1989; Hungerbühler, 2002; Stocker, 2010). None of the suspected juvenile specimens in this study had prenarial crests. I also compared the presence of a prenarial crest with prenarial size. Because not all the samples were labeled as juveniles or adults, factors such as larger prenarial size could indicate the presence of an adult (Brochu, 1992a; Brochu, 1992b; Fara and Hungerbühler, 2000; Irmis, 2007). My results show that no specimens with a prenarial length under

500mm contain a prenarial crest whereas the majority of specimens over 500mm do have a prenarial crest (60%). However, due to the small sample size (only eight specimens) I was unable to statistically validate my findings. When I compared my results to those of Fara and Hungerbühler (2000) the specimens TMM 43684-8, TMM 31173-120, and TMM 31173-121 all have a prenarial crest and are considered to be adults.

Diastemas, on the other hand, appear to be a common feature among phytosaurs. Over half of the specimens (57.14%) contained a diastema. Of those 47.38% contained at least two diastemas and 17.39% contained at least three. The vast majority of these diastemas are located in the premaxilla, particularly at the anterior end. Most were between the fourth and fifth premaxillary alveoli, the next most common position was between the third and fourth premaxillary alveoli, and additional ones were between the second and third premaxillary alveoli. What is interesting about these three locations is that the two most common locations for a diastema to appear are near the constriction of the rostrum where the premaxilla is the narrowest. The third most common location is at the terminal rosette where the premaxilla is at its widest. Because alveoli location has been linked to bite force and feeding patterns (Chatterjee, 1978; Hungerbühler, 2002; Erickson et al., 2003) the locations of these diastemas may have to do with improving the ability to capture and kill prey.

Another common feature was the presence of the alveolar ridge. 93.33% of the known samples have such a ridge with over a third having ridges labeled as small. Both the presence and the size of these ridges showed statistical significance. Based on this study it would seem that the presence of an alveolar ridge is a feature common to most phytosaurs.

The presence of the interpremaxillary fossa, however, is less common. Just under half of the samples (45.53%) have an interpremaxillary fossa (the majority were unknown). Of those most were wide (35.42%) while only a few (6.25%) were medium-sized, and 4.17% were narrow. There is no statistical significance between these sizes.

To look further into identifying morphological traits that could serve as ontogenic markers, I compared my resutls to those of Fara and Hungerbühler (2000). Based on their results none of my specimens would be considered juveniles except TMM 31173-121 and that is only for orbit diameter/skull width. In all other aspects TMM 31173-121 would be considered an adult. Looking through the data on this speimen it appears that the discrepency comes from the fact that the skull width on this specimen is fairly narrow. All other features are more adult-like, including the presence of a prenarial crest. On the other hand, according to the information of the identification card housed with TMM 31100-1332, it has suspected juvenile status.

I believe the inconsistencies between my results and those of Fara and Hungerbühler (2000) could be because of the following factors. First, my sample size was limited. Only four to five specimens had all the necessary features needed to do a comparision. This was because most of the samples I examined did not have many post narial features such as orbit diameter or total skull length. Specimens that did have those features were often crushed or missing bone fragments which made measuring these features difficult and subject to estimation. The second issue I had is that I could not compare snout length or snout width measurements to those of Fara and Hungerbühler (2000). This is because I measured the snout at different locations. I would like to go back and remeasure the snout length and widths at the same point as Fara and Hungerbühler (2000) so I could compare my results directly to theirs. Having those extra data points would be useful in answering the questions about the ontogeny of TMM 31173-121, TMM 311000-1332, and whether snout length and width measuremnts change the status of any of the other specimens in this study.

6b. Limitations

One limitation of this study is that the Texas Memorial Museum collection is biased towards elements from Howard County, TX. Close to 65% of recorded specimens were from that county. All remaining known specimens were are also from Texas, having been found in either Borden County or Crosby County. To my knowledge, none of the specimens include European, African or Indian specimens. In addition, I am also missing samples from New Mexico, Arizona and the rest of Texas so no broader inferences can be made about phytosaurs from the Southern United States. Therefore, all conclusions made about phytosaurs based on my data should be taken to apply to only three genera of phytosaurs found in these counties. Although similar patterns may exist for their European, African, Asian and other North American counterparts, conclusions about those can not be made with any certainty.

Another limitation was the variety (or lack thereof) of different species of phytosaurs. Only three genera were positively identified; *Paleohinus* (6.38%), *Angistorhinus* (10.64%), and *Leptosuchus* (4.26%). All others were either from unknown species or had the more inclusive identification of Phytosauridae. This probably has to do with two factors. The first is that all the known samples came from Crosby, Howard, and Borden counties, Texas. Most likely there were only a limited number of genera that lived and were fossilized in these areas. The second reason so few genera are represented is that the majority of materials are unidentified. This is because of a variety of factors, such as many specimen fragments are too small or are missing the necessary characteristics to classify them accurately. Many of the specimens cannot be identified because too much matrix is still on the bone or the bone is severely crushed. Additionally, for taxa that fall outside the expertise of staff at the Vertebrate Paleontology Lab, specimens are catalogued in a general way, and await experienced researchers to make the proper identifications. The lack of identification makes doing intraspecific and interspecific comparisons difficult.

The biggest limitation, however, was the inconclusive results I obtained when comparing my study with that of Fara and Hungerbühler (2000). Because I was not able to positively identify the samples as adults or juveniles I could not conduct the major analysis of identifying morphologic features that indicate ontogeny that that was the aim of this study. One of the reasons I could not identify more juveniles using criteria outlined by Fara and Hungerbühler (2000) was because many of the specimens in the study lacked one or more of the features that they used to determine ontogeny (orbital diameter, snout length/width, prenarial length/width, and total skull length). Most of the samples that I examined were of the premaxilla and/or maxilla. To determine ontogeny I would need features that were partially or completely postnarial. Other ontogenic markers such as neurocentral suture closures (Brochu, 1996; Irmis, 2007) also would not work for the same reason. I would need vertebral evidence which was not what I measured with these samples. Before determining premaxilla and maxilla features indicative of changes in ontogeny I need to find a way to determine which of these specimens do in fact appear to be juveniles.

6c. Future Work

There are many aspects of this study that I would like to rexamine or expand upon in future work. One of most prominent one would be expanding my sample size to include a wider variety of phytosaurs including those from Africa, Europe, India, and the rest of North America. That way I could determine if the features I found are unique to Texas phytosaurs (particularly ones in the southwest region of the state) or if these patterns exist across more taxa. Also, working within the TMM collection itself, there are still many samples left to be identified. By using existing diagnoses based on literature as well as the latest phylogenetic analysis of phytosaur relationships (Stocker, 2010; Nesbitt, 2011) I would like to identify more of the elements that I used in this study. That way I could do a more extensive analysis of each species and the characteristics they share, as well as those that differentiate species.

Another analysis I would like to conduct is to try to figure out why there were statistically more left-side alveoli in the premaxilla versus maxilla but the same pattern did not exist on the right-side elements. Because the premaxilla is longer than the maxilla in phytosaurs I would hypothesize that there would statistically be more alveoli in the premaxilla on both sides (right and left). I believe that I did not see this results because I lacked the necessary number of right-side elements to show a statistical difference. In the future I would like to use a larger sample size to see if my hypothesis is correct; that the premaxilla have more alveoli on average than the maxilla.

Many of my results on the size, shape, and location of heterodont alveoli in the premaxilla matched those of Hungerbühler (2000). Unfortunately, I was unable to confirm any of his findings on the maxillary alveoli because of an error I made when labeling. In the future I would like to reexamine the maxillary alveoli to see if I can obtain similar results. This would also help me analyze my hypothesis that alveolus size corresponds to premaxilla and maxilla width. By measuring the size of the maxillary alveoli, more alveoli in the premaxilla, and more widths along the premaxilla and maxilla I will be able to see if this hypothesis holds.

Another area where my study corresponded with the current literature was in the presence of prenarial crests. Prenarial crests have been hypothesized to be found only in adults (Camp, 1930; Ballew, 1986; Hungerbühler, 2002; Stocker, 2010). My results also showed that those specimens with prenarial crests had prenarial lengths greater than 500mm (many greater than 600mm) and were classified as adults based on the criteria used by Fara and Hungerbühler (2000). None of the specimens with prenarial lengths under 500mm or labeled as juveniles had prenarial crests. In the future I would like to expand on this research by examining more specimens with prenarial crests to measure not only their prenarial size but also their total skull length and other features such as the orbit-to-skull length and width ratios (Fara and Hungerbühler, 2000).

Another potential ontogenetically variable feature could be the number and location of diastemas in the premaxilla and maxilla. I would like to see if the size of the premaxillae or maxillae has any correlation to the presence and number of diastemas. For example, if diastemas are more prevalent on larger specimens this could serve as an indicator for determining ontogeny. In addition, I would like to study if the location of the diastema is a factor in improving bite force and the ability of phytosaurs to obtain prey. These two research avenues may be related. In *Alligator mississippiensis* (an extant archosaur) the juveniles feed on different prey items than the adults. As they mature and grow they undergo many morphological changes particularly in their dentition (Erickson et al., 2003). If phytosaurs follow the same pattern, then the disappearance or emergence of diastemas with ontogeny could be related to changes in feeding patterns from juvenile to adult.

Within the samples I studied the presence of the interpremaxillary fossa and alveolar ridge were common. In the future I would like to examine the unknown samples further, as well as other genera of phytosaurs, to see if these two features are ubiquitous among phytosaurs or if their presence varies among specimens and species. I would also like to examine the differences in the sizes of the interpremaxillary fossa and alveolar ridge to see if there is any correlation between the size or width and ontogeny.

Of course, the most important aspect I need to address is developing a way to verify whether the samples I am using are more representative of juveniles or adults. Until I can do that I can not determine if these other features (such as diastema number and location, interpremaxillary fossa, and alveolar ridge and the presence or absence of prenarial crests) are effective morphological markers of young individuals. Right now the most effective tool I could use to determine ontogenetic age is the total size of the premaxilla and/or maxilla. However, as I discussed before, size can be misleading especially when dealing with different genera and sexes of phytosaurs. Having additional morphological features that are independent of size would help validate my results.

CHAPTER SEVEN: APPLICATIONS TO PRACTICE

One of my biggest goals as a science teacher is to expose my students to primary and current scientific research. Many students have several misconceptions about scientists and how science is done in the 'real world' that stems for a lack of personal knowledge. Few high school students know any practicing scientists, and it is the rare student that has ever been in a research lab or facility. Therefore, many students have developed an idea of science and scientists as a few brilliant individuals working in isolation to develop groundbreaking, singular discoveries. This is a notion fortified by what they read in their books and by what is taught in the classroom. One of the best ways to break those stereotypes is to expose students to contemporary research and the individuals who are doing it.

Visiting most scientists and their labs is difficult for me and my students. I teach in the Rio Grande Valley, a historically underfunded and impoverished area. Even though we do have a research institution in the area (The University of Texas-Pan American), we cannot afford the transportation costs to take the students on a visit. Funding aside, our school year is tightly regulated by high stakes standardized testing that leaves us with few free class days we can use to take a field trip. In adition, bringing high school students to these research instructions is taxing on the institution itself because many labs are too small to do an effective tour.

What is more accessible to me and my students is scientific research. By having students read primary research articles it exposes them to the language, procedures, questions, communication and scientific world that exist. Therefore, as my teaching connection I selected one of the scientific papers I used in my research (Brochu, 1996) for the students to read. I also wrote a corresponding 5E lesson plan to accompany the paper. I selected Brochu (1996) because it serves as a good introduction to the problems associated with determining the maturity of organisms. It also provides a unique answer to determine maturity in certain taxa that has been pivotal for those studying Crocodylia and their relatives. The paper also provides graphs, charts and pictures that the students can look through and interpret. Finally, there are many papers and research that follow Brochu's that explore similar ideas. These papers I can use as an extension with my gifted and talented students or with the entire class if we have the opportunity to read more primary literature articles.

5E Lesson Plan:

Scientific Article: Brochu, C.A. 1996. Closure of Neurocentral Sutures during Crocodilian Ontogeny: Implications for Maturity Assessment in Fossil Archosaurs. Journal of Vertebrate Paleontology 16:49-62.

Time Frame: 2 day lesson (plus time at home to finish reading the article).

Subject / grade level: Ninth grade pre-AP biology.

Materials: Copy of scientific article (one per student), paper, colors (pencils, crayons or markers), and juvenile and adult animal cards (one per group of students).

Texas Essential Knowledge and Standards (TEKS) (Texas Education Agency, 2010).

(c) Knowledge and skills.

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(B) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;

(E) plan and implement descriptive, comparative, and experimental investigations, including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(F) collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as calculators, spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, stereoscopes, metric rulers, electronic balances, gel electrophoresis apparatuses, micropipettes, hand lenses, Celsius thermometers, hot plates, lab notebooks or journals, timing devices, cameras, Petri dishes, lab incubators, dissection equipment, meter sticks, and models, diagrams, or samples of biological specimens or structures;

(G) analyze, evaluate, make inferences, and predict trends from data; and

(H) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) draw inferences based on data related to promotional materials for products and services;

(D) evaluate the impact of scientific research on society and the environment;

(E) evaluate models according to their limitations in representing biological objects or events

(F) research and describe the history of biology and contributions of scientists.

Lesson objective(s): The objective of this lesson is to have students determine what factors might indicate that an organism has reached maturity or adulthood. Students will then evaluate the effectiveness of each of these factors as well as their limitations.

Differentiation strategies to meet diverse learner needs:

English as Second Language (ESL or LEP) students:

- For these students we will make a word wall as we go through the lesson. Each time we come to a new vocabulary word we will write it on the wall and then define it with either words or pictures. The word wall will stay up throughout the lesson so students can always refer back to it if they are having trouble remember what a term or idea means.

- If possible print an additional copy of the paper in the student's native language.
- Provide dictionaries or translation materials/resources so students can look up words they do not know.

Special Education and 504 students:

- Have students only read sections of the paper instead of the whole thing. Alternatively have the students read the paper in class in a 'round robin' style.
- Provide students with a 'cheat sheet' that explains the major concepts of the paper. Incorporate lots of images in the cheat sheet to help explain the ideas and concepts in the paper.

Gifted and Talented students:

- As a follow up to this lesson have students read: Irmis, R. B. 2007. Axial skeleton ontogeny in the Parasuchia (Archosauria: Pseudosuchia) and its implications for ontogenetic determination in Archosaurs. Journal of Vertebrate Paleontology 27(2):350-261.
- Have students compare and contrast the two papers. Also, have students discuss what new challenges come from determining maturity in extinct species versus extant ones.

ENGAGEMENT (DAY 1: 15-20 minutes)

- On cards have pictures of different animals in both their juvenile and adult forms. You can choose different animals but here are some suggestions: a cichlid (or other fish), a dragonfly, a snake, a frog, a peacock or swan, a fox (or other mammal), a jellyfish (also get a picture of the jellyfish in the poly phase) and a human.

- Mix up the cards and give one set to each group of 4-5 students.
- Tell the students they have five minutes to sort the cards into which organisms they think are juveniles and which ones they think are mature adults. Do not tell the students that the cards are paired (one juvenile and one adult per organism).
- At the end of five minutes have the students stop and briefly discuss (about 2 minutes per group) how they divided up their cards. Have them discuss what factors they used to determine whether an organism was an adult or a juvenile.
    - Discussion Questions:
        - How do you define an adult? How do you define a juvenile?
        - How did you determine whether an organism was an adult or a juvenile?
        - Are there certain factors you used to make your decision?
        - Do you think the factors you selected were good indicators for determining adult status or maturity?
- Now show the students the correct answers. Go through each organism and show which card is the juvenile and which is the adult.
    - Discussion Questions:
        - What differences and similarities do you notice between the juvenile and adult?
        - Are any of these surprising?

        - Evolutionarily, why might some organisms look different as juveniles versus adults?
        - Evolutionarily, why might some organisms look basically the same as juveniles versus adults?
        - Do you still think the factors you selected were good indicators for determining adult status or maturity?
        - What new factors might you want to include?
        - Imagine you are a scientist studying and extinct species. Would it be easier or harder to determine if the fossil you found is a juvenile or adult? Why?
- Now that you've gone through the activity have the students spend about five minutes brainstorming ways to determine if an organism has reached maturity. Write the answers on the board.
    - Discussion Questions:
        - Why is knowing the general age of an organism important?
        - Why is this important for extinct species?
- Collect the cards from the students.

EXPLORATION (DAY 1: 30-40 minutes class time plus time at home)

- Pass out the Brochu paper to each student.
- Explain that in this paper Brochu hypothesized that size is not always a good indicator of maturity. Factors such as sexual dimorphisms, dwarf species, nutritional state, incubation temperature, and population size can all impact the

terminal size of mature individuals (define each of those terms or ideas to the class as you go through). To develop a better measure than size, Brochu measured the neurocentral suture closures in the vertebra of crocodiles (explain what neurocentral sutures are – use lots of pictures).

- Explain to the students they will use the remainder of their class time to read the paper silently in class. That way if they have any question they can ask you. Whatever they don't finish they can bring home to read for homework. Tell them to take notes as they go and write down any questions they might have. That way they can ask them tomorrow in class.
- Tell students that as they are reading to pay close attention to the following items. Have them write down their answers on a spate sheet of paper:
    - Discussion Question:
        - What is the problem Brochu is trying to solve?
        - Why is solving this problem important?
        - What is his hypothesis?
        - How does he go about doing his experiment?
        - Do you think he set up a good experiment? What do you like? What do you think he could or should have done differently?
        - What results did he get?
        - What was his conclusion?
        - Did he except or reject his hypothesis?
        - What are the implications this study?

    - Overall, what did you think of his research and the results he obtained?

EXPLANATION (DAY 2: 20 minutes)

- Begin day two by having students take out their papers. Start by answering any questions the students might have.
- When you are done answering questions go through the discussion questions you gave the students yesterday to work through as they read the paper. This time, however, discuss the answers as a class. Have students correct or add notes to their own personal answers.
  - Discussion Question:
    - What is the problem Brochu is trying to solve?
    - Why is solving this problem important?
    - What is his hypothesis?
    - How does he go about doing his experiment?
    - Do you think he set up a good experiment? What do you like? What do you think he could or should have done differently?
    - What results did he get?
    - What was his conclusion?
    - Did he except or reject his hypothesis?
    - What are the implications this study?
    - Overall, what did you think of his research and the results he obtained?

- Also discuss what it was like reading a scientific paper:
    - Discussion Questions:
        - What was hard about reading a scientific paper?
        - What would have made reading this paper easier?
        - Did you enjoy reading this paper? Would you like to read more scientific papers in the future? What types of papers or research would you be interested in?

ELABORATION (DAY 2: 20 minutes)

- Now have the students create their own ‘matrix of maturity.’ Have the students break up into groups of 3-4. Tell each group to pick an organism.
- On a sheet of construction or butcher paper have the students spend 10-15 minutes drawing their organism and writing down different morphological features they would use to predict the relative age and maturity of that organism.
- At the end of this time give each group 2-3 minutes to present their ‘matrix of maturity’ to the class.
    - Discussion Questions:
        - What morphological features did you select to determine the relative age or maturity of that organism?
        - What are some potential issues that might come up with some of your features?
        - Based on the features on your list which ones might be more effective to use and why?

- Could you use your index to predict the age or maturity of a different organism? An extinct organism? What might you need to change or do differently?

EVALUATION (DAY 2: 10 minutes)

- Have the students switch organism with another group. For example, the students that made their matrix for a mouse switch with a group that made their matrix for a frog.
- Have each group try to use their matrix to determine the age or maturity of their new organism. On the back of their paper have each group write a paragraph answering the following questions:
    - What features on your matrix do a good job identifying the maturity of the new organism? Why?
    - What features do a poor job of identifying the maturity of your new organism? Why?
    - How will you modify your index to be a better indicator?
    - Is it better to have one index that determines the maturity of all organisms or should there be different indices to measure the maturity of different organisms? Explain your answer.

APPENDIX

Specimen Number	Taxon	Locality	Geographic Area	Collection Site	Material	Right Premaxilla Alveoli	Left Premaxilla Alveoli	Right Maxilla Aveloi	Left Maxilla Aveloi	Right Total Aveoli
TMM 31173-120				Classroom	Complete skull	21	21	21	21	42
TMM 31213-16	*Paleorhinus*	B-1-1-41	Borden Co., TX.	Classroom	Mostly complete skull	22	21	18	18	40
TMM 31025-56		HO-3-Q1-1169-40	Howard Co., TX.	11-C1	Right and Left Premaxillae	at least 14	at least 13	Inc.	Inc.	at least 14
TMM 31025-179			Howard Co., TX.	11-C1	Right and left maxillae	Inc.	Inc.	at least 6	at least 16	at least 6
TMM 31025-179			Howard Co., TX.	11-C1	Left maxillae	N/A	Inc.	N/A	at least 12	N/A
TMM 31025-179			Howard Co., TX.	11-C1	Left. Premax	N/A	at least 14	N/A	Inc.	N/A
TMM 31100-11		HO-3-03-1-40	Howard Co., TX.	11-F1	Left premax. Fragment; Left max. frag.	N/A	at least 20	N/A	at least 10	N/A
TMM 31100-126			Howard Co., TX.	11-F2	Right and Left maxillae fragment	Inc.	Inc.	at least 22	at least 18	at least 22
TMM 31100-126			Howard Co., TX.	11-F2	Right and Left Premaxillae	at least 8	at least 9	Inc.	Inc.	at least 8
TMM 31100-463				11-F7	Right and Left Premaxillae frag.	at least 9	at least 12	Inc.	Inc.	at least 9
TMM 31100-382			Howard Co., TX.	11-F8	Left premax.	N/A	at least 9	N/A	Inc.	N/A
TMM 31100-12		HO-3-Q3-189-40	Howard Co., TX.	11-F8	Right and Left Rostrum	19	at least 18	at least 1	Inc.	at least 20
TMM 31100-162		HO-3-Q3-351-40	Howard Co., TX.	11-F9	Left maxillae	N/A	Inc.	N/A	at least 11	N/A
TMM 31100-318		HO-3-Q3-2-40	Howard Co., TX.	11-F10	Left maxillae frag.	N/A	Inc.	N/A	at least 10	N/A
TMM 31100-318		HO-3-Q3-2-40	Howard Co., TX.	11-F10	Left premax. frag	N/A	at least 23	N/A	Inc.	N/A
TMM 31100-286		HO-3-Q3-369-40	Howard Co., TX.	11-F12	Left maxillae	N/A	Inc.	N/A	at least 18	N/A
TMM 31100-8	*Angistorhinus*	HO-3-Q3-186-40	Howard Co., TX.	11-F13	Postorbital portion skull	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-239	*Paleohinus ehlersi*			11-F13	Complete skull	26	25	21	18	43
TMM 31185-43			Howard Co., TX.	11-G2	Left skull fragment	N/A	21	N/A	at least 18	N/A
TMM 31098-37	*Paleorhinus or Angistorhinus*	H0-3-41-39 incorrect?	Howard Co., TX.	11-H4	Left premax/max.	N/A	at least 16	N/A	at least 11	N/A
TMM 31098-18		HO-3-19-39	Howard Co., TX.	11-H4	Right and Left premax/max.	at least 16	at least 16	at least 11	at least 10	at least 27
TMM 31098-30		HO-3-27-39	Howard Co., TX.	11-H4	Rostrum	at least 7	at least 7	Inc.	Inc.	at least 7
TMM 31098-30		HO-3-278-39	Howard Co., TX.	11-H4	Left skull fragment	N/A	at least 22	N/A	at least 8	N/A
TMM 31098-47		HO-3-2-39	Howard Co., TX.	11-I5	Right and Left Rostrum	at least 5	at least 8	Inc.	Inc.	at least 5
TMM 31098-47		HO-3-2-39	Howard Co., TX.	11-I5	Left skull fragment	N/A	at least 6	N/A	Inc.	N/A
TMM 31100-1378		HO-3-Q3-367-40	Howard Co., TX.	11-I30	Right premax. Frag.	at least 6	N/A	Inc.	N/A	at least 6
TMM 31100-1361		HO-3-Q3-367-40	Howard Co., TX.	11-I30	Right maxillae	Inc.	N/A	at least 12	N/A	at least 12
TMM 3100-1496		HO-3-Q3-320-40	Howard Co., TX.	11-J7	Left premax/max.	N/A	at least 20	N/A	at least 2	N/A
TMM 3100-1498		HO-3-Q3-312-40	Howard Co., TX.	11-J7	Rostrum and skull fragment	at least 13	at least 9	at least 8	at least 8	at least 21
TMM 3100-1497		HO-3-Q3-312-40	Howard Co., TX.	11-J7	Right premax/max	at least 18	N/A	at least 27	N/A	at least 45
TMM 31100-1495				11-J10	Right and Left Rostrum	at least 4	at least 4	Inc.	Inc.	at least 4
TMM 31100-1020		HO-3-Q3-5-40	Howard Co., TX.	11-K6	Right premax/max	at least 13	N/A	at least 13	N/A	at least 26
TMM 43684-8	*Leptosuchus adamanensis*			11-L10	Almost complete skull	12	11	at least 27	at least 13	at least 39
TMM 43685-373		PRO-02-01		11-M9	Right maxilla frag.	Inc.	N/A	at least 4	N/A	at least 4
TMM 31173-7			Crosby Co., Tx	12-R8	Right maxillae frag. (?)	Inc.	N/A	at least 9	N/A	at least 9
TMM 31173-48			Crosby Co., Tx	12-R9	Rostrum	at least 6	at least 5	at least 8	at least 8	at least 14
TMM 31173-51			Crosby Co., Tx	12-R9	Rostrum	12	11	at least 2	at least 2	at least 14
TMM 31173-109			Crosby Co., Tx	12-R11	Left premax. Frag.	N/A	at least 8	N/A	Inc.	N/A
TMM 31173-114			Crosby Co., Tx	12-R11	Right premax.	at least 6	N/A	Inc.	N/A	at least 6
TMM 31172-25			Crosby Co., Tx	12-Q2	Right and Left Premaxillae	at least 21	at least 25	Inc.	Inc.	at least 21
TMM 31172-19			Crosby Co., Tx	12-Q3	Rostrum	at least 4	at least 3	Inc.	Inc.	at least 4
TMM 31173-81	*Phytosauridae*	CR-121-2-40	Crosby Co., Tx	Basement	Rostrum	at least 8	9	at least 11	at least 9	at least 19

TMM 31098-2	*Angistorhinus*	Howard Co., TX.	Basement	Rostrum	25	at least 21	at least 5	at least 4	at least 30
TMM 31098-2		*Angisorhinus*		Howard Co., TX.		11-H4		Skull fragments	
TMM 31100-175	*Angistorhinus*	Howard Co., TX.	Basement	Complete rostrum and almost complete maxillae	23	23	at least 15	at least 15	at least 38
TMM 31100-418		Basement	Almost complete skull		19		at least 17	at least 36	
TMM 31100-1332	*Angisorhinus alticephalus*	Howard Co., TX.	Restoration Room	Complete skull	at least 21	at least 22	at least 11	at least 21	at least 32
TMM 31173-121	*Leptosuchus*	Crosby Co., Tx, Brunson Ranch	Basement	Complete skull	at least 16	at least 20	at least 14	at least 15	at least 30

Specimen Number	**Left Total Aveoli**	**Alveolar Ridge**	**Interpremaxilla fossa (No, small, wide)**	**Diastema Present**	**Prenarial Crest**	**Right Width Premaxilla (2)**	**Left Width Premaxilla (2)**	**Right Width Premaxilla (4-5)**
TMM 31173-120	42	Y	Wide	Y: 2-3; 4-5	Y?	34.75mm	28.50mm	16.02mm
TMM 31213-16	39	Y	Wide	Y: 3-4; 4-5; 20-21		30.00mm	29.70mm	20.99mm
TMM 31025-56	at least 13	Y	Small	Y: 4-5	N	10.20mm	10.41mm	7.29mm
TMM 31025-179	at least 16	Y: small	?	N	N	Inc.	Inc.	Inc.
TMM 31025-179	at least 12	Y: small	?	N	N	N/A	Inc.	N/A
TMM 31025-179	at least 14	Y	?	Y: 4-5	N	N/A	10.35mm	N/A
TMM 31100-11	at least 30	N	?	N	Y	N/A	Inc.	N/A
TMM 31100-126	at least 18	Y	Small	N	N	Inc.	Inc.	Inc.
TMM 31100-126	at least 9	Y	Med.	Y: 2-3; 3-4; 4-5	N	16.66mm	16.88mm	11.02mm
TMM 31100-463	at least 12	Y: small	?	Y: 3-4(?)	N	10.26mm?	Inc.	6.98mm?
TMM 31100-382	at least 9	Y: small	?	Y: 3-4	N	N/A	8.29mm	N/A
TMM 31100-12	at least 18	Y	Wide	Y: 3-4	N	27.24mm	28.90mm	21.22mm
TMM 31100-162	at least 11	N	?	N	N	N/A	Inc.	N/A
TMM 31100-318	at least 10	Y: small	?	N	N	N/A	Inc.	N/A
TMM 31100-318	at least 23	Y: small	?	Y: 2-3?	N	N/A	9.43mm	N/A
TMM 31100-286	at least 18	Y: small	?	N	N	N/A	Inc.	N/A
TMM 31100-8	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-239	43	Y	Wide	Y: 4-5 L: 17-18; 27-28	N	15.27mm	20.33mm	12.13mm
TMM 31185-43	at least 39	Y: small	?	Y: 3-4; 32-33	N	N/A	14.01mm	N/A
TMM 31098-37	at least 27	Y: small	?	N	N	N/A	Inc.	N/A
TMM 31098-18	at least 26	Y	?	Y	N	Inc.	Inc.	15.59mm
TMM 31098-30	at least 7	Y	Wide	N	N	Inc.	Inc.	Inc.
TMM 31098-30	at least 30	Y: small	?	Y: 2-3	N	N/A	Inc.	N/A
TMM 31098-47	at least 8	Y	Wide	N	N	Inc.	Inc.	Inc.
TMM 31098-47	at least 6	Y; small	?	N	N	N/A	Inc.	N/A
TMM 31100-1378	N/A	N	?	?	N	19.57mm	N/A	15.35mm
TMM 31100-1361	N/A	?	?	N	?	Inc.	N/A	Inc.
TMM 3100-1496	at least 21	Y	?	Y: 3-4; 4-5	?	N/A	9.83mm	N/A
TMM 3100-1498	at least 17	Y: small	Wide	?	N	Inc.	Inc.	Inc.
TMM 3100-1497	N/A	Y: small	?	Y: 3-4; 4-5	N	15.45mm	N/A	10.45mm
TMM 31100-1495	at least 4	Y	Wide	N	N	Inc.	Inc.	Inc.
TMM 31100-1020	N/A	Y	?	?	N	Inc.	N/A	Inc.
TMM 43684-8	at least 24	Y	Wide	Y: 3-4	Y	43.33mm	44.75mm	26.55mm
TMM 43685-373	N/A	Y	Wide	N	N	Inc.	N/A	Inc.
TMM 31173-7	N/A	Y: small	?	N	N	Inc.	N/A	Inc.
TMM 31173-48	at least 13	Y	Wide	N	N	Inc.	Inc.	Inc.
TMM 31173-51	at least 13	Y	Wide	Y: 2-3; 4-5	N	27.29mm	33.39mm	22.28mm
TMM 31173-109	at least 8	Y: small	?	N	N	N/A	Inc.	N/A
TMM 31173-114	N/A	Y: small	?	N	N	Inc.	N/A	Inc.
TMM 31172-25	at least 25	Y	?	Y: 3-4; 4-5	N	8.02mm	7.60mm	4.58mm
TMM 31172-19	at least 3	Y	Wide	?	N	52.55mm	51.44mm	Inc.
TMM 31173-81	at least 18	Y	Wide	Y: 2-3; 4-5	N	58.55mm	61.75mm	45.25mm
TMM 31098-2	at least 25	Y	Wide	Y: 2-3; 4-5	N	57.75mm	50.01mm	39.78mm
TMM 31098-2								
TMM 31100-175	at least 38	Y	Wide	Y: 2-3; 4-5	N	30.74mm	33.29mm	24.96mm
TMM 31100-418	Y	Med.		Y: 3-4; 4-5	20.49mm	22.76mm	14.60mm	
TMM 31100-1332	at least 43	Y	Med.	Y: 2-3; 3-4; 4-5?	N	24.95mm	24.40mm	15.03mm
TMM 31173-121	at least 35	Y	Wide	Y: 2-3; 3-4?	Y	36.53mm	32.46mm	34.78mm

Specimen Number	**Left Width Premaxilla (4-5)**	**Right Width Premaxilla/Maxilla**	**Left Width Premaxilla/Maxilla**	**Right Length Alveolus (2)**	**Left Length Alveolus (2)**	**Right Width Alveolus (2)**	**Left Width Alveolus (2)**	**Right Length Alveolus (4)**
TMM 31173-120	16.40mm	22.53mm	23.00mm	15.70mm	14.40mm	13.72mm	13.85mm	7.52.mm

TMM 31213-16	25.10mm	31.25mm	36.95mm	17.74mm	20.22mm	12.10mm	14.50mm	8.42mm
TMM 31025-56	7.25mm	Inc.	Inc.	6.94mm	7.98mm	4.30mm	5.43mm	4.25mm
TMM 31025-179	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31025-179	7.53mm	N/A	Inc.	N/A	6.22mm	N/A	5.05mm	N/A
TMM 31100-11	20.55mm (not sure, can't number teeth)	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-126	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-126	11.96mm	Inc.	Inc.	5.22mm	7.55mm	4.00mm	6.81mm	5.15mm (5)
TMM 31100-463	Inc.	Inc.	Inc.	6.17mm?	Inc.	6.00mm?	Inc.	2.63mm?
TMM 31100-382	Inc.	N/A	Inc.	N/A	3.27mm	N/A	3.02mm	N/A
TMM 31100-12	20.99mm	29.61mm	Inc.	18.50mm	18.66mm	16.92mm	16.33mm	11.40mm
TMM 31100-162	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-318	Inc.	N/A	12.00mm	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-318	7.90mm?	N/A	12.00mm	N/A	4.65mm	N/A	3.85mm	N/A
TMM 31100-286	Inc.	N/A	~9.79mm	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-8	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-239	12.54mm	17.10mm	17.45mm	9.73mm	7.06mm	8.08mm	6.45mm	4.88mm
TMM 31185-43	10.92mm	N/A	17.22mm	N/A	4.75mm	N/A	5.06mm	N/A
TMM 31098-37	Inc.	N/A	14.65mm	N/A	Inc.	N/A	Inc.	N/A
TMM 31098-18	13.01mm	17.74mm	17.29mm	Inc.	Inc.	Inc.	Inc.	2.67mm
TMM 31098-30	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31098-30	20.01mm	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31098-47	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-1378	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	4.72mm (4?)
TMM 31100-1361	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 3100-1496	8.06mm	N/A	14.00mm	N/A	5.90mm	N/A	4.29mm	N/A
TMM 3100-1498	Inc.	28.76mm	Left rostrum crushed to side so can't take measurement	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 3100-1497	N/A	14.99mm	N/A	8.50mm	N/A	7.85mm	N/A	4.30mm
TMM 31100-1495	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-1020	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 43684-8	34.09mm	34.28mm	33.66mm	23.80mm	22.54mm	14.999mm	17.45mm	5.65mm
TMM 43685-373	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31173-7	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31173-48	Inc.	22.00mm	24.07mm	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31173-51	27.06mm	23.60mm	23.04mm	17.18mm	22.50mm	13.05mm	18.23mm	7.35mm
TMM 31173-109	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31173-114	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31172-25	4.32mm	Inc.	Inc.	4.18mm	4.12mm	3.97mm	4.88mm	2.19mm
TMM 31172-19	Inc.	Inc.	Inc.	21.08mm	13.72mm	25.10mm	17.22mm	Inc.
TMM 31173-81	45.36mm	46.06mm	46.25mm	38.65mm	20.90mm	27.81mm	25.00mm	15.57mm
TMM 31098-2	35.20mm	49.15mm	44.73mm	31.10mm	22.55mm	25.22mm	16.00mm	9.80mm
TMM 31098-2								
TMM 31100-175	22.45mm	32.75mm	28.79mm	16.34mm	18.05mm	12.28mm	13.05mm	5.55mm (5)
TMM 31100-418	11.98mm	22.51mm	19.95mm	10.06mm	9.80mm	7.97mm	8.14mm	3.53mm
TMM 31100-1332	18.38mm	30.47mm	26.73mm	17.45mm	11.05mm	16.40mm	8.31mm	4.57mm?
TMM 31173-121	23.26mm	36.35mm	15.42mm	18.52mm	16.26mm	15.55mm	13.66mm	6.38mm

Specimen Number	**Left Length Alveolus (4)**	**Right Width Alveolus (4)**	**Left Width Alveolus (4)**	**Right Length Alveolus (15)**	**Left Length Alveolus (15)**	**Right Width Alveolus (15)**	**Left Width Alveolus (15)**	**Right Length Alveolus (31)**
TMM 31173-120	8.00mm	6.02mm	8.78mm	8.98mm	8.65mm	7.98mm	7.91mm	12.23mm
TMM 31213-16	7.23mm	7.50mm	9.25mm	14.31mm	12.40mm	19.01mm	12.70mm	24.10mm
TMM 31025-56	3.48mm	3.85mm	4.00mm	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31025-179	3.17mm	N/A	2.84mm	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-11	9.25mm (not sure if 4)	N/A	7.95mm (not sure if 4)	N/A	9.08mm (not sure it's 15)	N/A	8.15mm (not sure if 15)	N/A
TMM 31100-126	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	6.09mm (not sure if 31)
TMM 31100-126	4.68mm	4.49mm (5)	4.30mm	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-463	Inc.	1.95mm?	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-382	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-12	11.74mm	9.48mm	11.28mm	13.99mm	12.74mm	12.05mm	11.59mm	Inc.
TMM 31100-162	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-318	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A

TMM 31100-318	1.30mm?	N/A	1.75mm?	N/A	4.98mm?	N/A	3.84mm?	N/A
TMM 31100-286	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-8	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-239	3.92mm	4.63mm	4.74mm	5.35mm	4.86mm	5.24mm	4.74mm	7.52mm
TMM 31185-43	5.50mm	N/A	4.68mm	N/A	7.67mm	N/A	6.44mm	N/A
TMM 31098-37	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31098-18	2.72mm	3.10mm	2.42mm	5.04mm	5.63mm	5.33mm	4.68mm	Inc.
TMM 31098-30	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31098-30	7.11mm (6?)	N/A	8.95mm	N/A	7.72mm (15?)	N/A	8.44mm (15?)	N/A
TMM 31098-47	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31100-1378	N/A	4.26mm (4?)	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31100-1361	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 3100-1496	2.93mm	N/A	3.29mm	N/A	4.91mm	N/A	3.21mm	N/A
TMM 3100-1498	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 3100-1497	N/A	3.56mm	N/A	4.31mm	N/A	3.90mm	N/A	6.65mm
TMM 31100-1495	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31100-1020	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 43684-8	7.65mm	5.62mm	8.22mm	14.69mm	11.01mm	12.99mm	12.03mm	Inc.
TMM 43685-373	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31173-7	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31173-48	Inc.	Inc.	Inc.	10.75mm (15?)	11.54mm (15?)	10.03mm (15?)	11.25mm (15?)	Inc.
TMM 31173-51	8.99mm	7.48mm	7.70mm	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31173-109	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A
TMM 31173-114	N/A	Inc.	N/A	Inc.	N/A	Inc.	N/A	Inc.
TMM 31172-25	1.90mm (5)	2.18mm	1.69mm (5)	3.17mm	3.52mm	3.01mm	2.99mm	Inc.
TMM 31172-19	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
TMM 31173-81	11.67mm	19.56mm	14.98mm	15.22mm	16.01mm	24.41mm	14.99mm	Inc.
TMM 31098-2	9.36mm	11.75mm	7.27mm	15.62mm	10.22mm	15.58mm	12.44mm	Inc.
TMM 31098-2								
TMM 31100-175	7.25mm (5)	5.94mm (5)	6.45mm (5)	9.34mm	5.04mm	8.74mm	5.15mm	8.90mm
TMM 31100-418	6.37mm?	3.78mm	4.46mm?	5.35mm	8.30mm	5.07mm	7.15mm	10.41mm
TMM 31100-1332	7.01mm	4.14mm?	4.40mm	8.23mm (14)	7.15mm	7.04mm (14)	6.18mm	~8.96mm
TMM 31173-121	8.98mm	6.79mm	7.16mm	5.57mm	11.70mm	16.26mm	8.34mm	10.66mm

Specimen Number	**Left Length Alveolus (31)**	**Right Width Alveolus (31)**	**Left Width Alveolus (31)**	**Alveoli Uniform?**	**Total Rostrum Width**	**Prenarial length**	**Maxillary Length**	**Postorbital Width**
TMM 31173-120	12.72mm	13.61mm	15.46mm	Most teeth round, 30-39 more ovular	39.18mm	610.0mm	348.0mm	59.5mm
TMM 31213-16	18.03mm	31.40mm	22.52mm	Teeth more irregular, vary more in shape	63.24mm	N/A	374.0mm	N/A
TMM 31025-56	Inc.	Inc.	Inc.	Yes	at least 16.25mm	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	Inc.	Inc.	Round, large, some seem crushed on the	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	N/A	Inc.	Round, evenly spaced, some aveoli	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	N/A	Inc.	Large, round, lots of spacing between	Inc.	Inc.	Inc.	Inc.
TMM 31100-11	Inc.	N/A	Inc.	Round large, evenly spaced	at least 40.40mm	Inc.	at least 244.0mm	Inc.
TMM 31100-126	5.51mm (not sure if 31)	6.50mm (not sure if 31)	5.70mm (not sure if 31)	Small, round, evenly spaced (many	Inc.	Inc.	Inc.	Inc.
TMM 31100-126	Inc.	Inc.	Inc.	Small, round, lots of spaceing. Many	26.85mm	Inc.	Inc.	Inc.
TMM 31100-463	Inc.	Inc.	Inc.	Large at terminal rossett, small and	Inc.	Inc.	Inc	Inc.
TMM 31100-382	Inc.	N/A	Inc.	Small round, some gaps maybe due to	at least 14.30mm	Inc.	Inc.	Inc.
TMM 31100-12	Inc.	Inc.	Inc.	Round, close together, get smaller	41.69mm	Inc.	Inc.	Inc.
TMM 31100-162	Inc.	N/A	Inc.	Medium sized and round, somewhat	Inc.	Inc.	Inc.	Inc.
TMM 31100-318	Inc.	N/A	Inc.	Anteriorly-posteriorly elongated, fairly even	Inc.	Inc.	Inc.	Inc.

TMM 31100-318	Inc.	N/A	Inc.	Most of the anterior aveloi are difficult to	Inc.	Inc.	Inc.	Inc.
TMM 31100-286	Inc.	N/A	Inc.	Round at the most anterior and	Inc.	Inc.	~170.40mm	Inc.
TMM 31100-8	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc	~ 110mm
TMM 31100-239	6.81mm	6.95mm	6.86mm	Mostly round and uniform, evenly	26.03mm	332.0mm	184.0mm	90mm
TMM 31185-43	9.66mm	N/A	8.21mm	Round but teeth become larger and	27.76mm	284.0mm	220.0mm	Inc.
TMM 31098-37	Inc.	N/A	Inc.	Many poorly preserved so difficult	Inc.	Inc.	Inc.	Inc.
TMM 31098-18	Inc.	Inc.	Inc.	Round; close together anteriroly,	27.83mm (7?)	Inc.	Inc	Inc.
TMM 31098-30	Inc.	Inc.	Inc.	Round, evenly spaced	21.06mm (7?)	Inc.	Inc.	Inc.
TMM 31098-30	Inc.	N/A	Inc.	Sound, fairly evenly spaced, get larger as	at least 44.98mm	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	Inc.	Inc.	Aveoli socks not very clean so hard to tell	43.53 (7?)	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	N/A	Inc.	Aveoli socks not very clean so hard to tell	Inc.	Inc.	Inc.	Inc.
TMM 31100-1378	N/A	Inc.	N/A	Small, round, spacing hard to determine	Inc.	Inc.	Inc.	Inc.
TMM 31100-1361	N/A	Inc.	N/A	Seem small, round and evely spaced but	Inc.	Inc.	Inc.	Inc.
TMM 3100-1496	Inc.	N/A	Inc.	Large, round, evenly spaced, lots of	at least 18.70mm	Inc.	Inc.	Inc.
TMM 3100-1498	Inc.	Inc.	Inc.	Difficult to see but appear uniform,	Left rostrum crushed to side so can't take	at least 256.0mm	Inc.	Inc.
TMM 3100-1497	N/A	3.71mm	N/A	Mostly roundand evenly spaced; more	at least 20.62mm	Inc.	Inc.	Inc.
TMM 31100-1495	Inc.	Inc.	Inc.	Aveoli poorly preserved; on the	Inc.	Inc.	Inc.	Inc.
TMM 31100-1020	N/A	Inc.	N/A	Most aveoli too poorly preserved to	Inc.	Inc.	Inc	Inc.
TMM 43684-8	Inc.	Inc.	Inc.	Very large anteriorly, R aveoli 3 sticks out,	59.83mm	at least 504.9mm	at least 259.0mm	~120mm
TMM 43685-373	N/A	Inc.	N/A	Large ovular aveoli, very deep, close	Inc.	Inc.	Inc	Inc.
TMM 31173-7	N/A	Inc.	N/A	Round, hard to distinguish due to	Inc.	Inc.	Inc.	Inc.
TMM 31173-48	Inc.	Inc.	Inc.	Round, uniform, some uneven spacing	Inc.	Inc.	Inc.	Inc.
TMM 31173-51	Inc.	Inc.	Inc.	Round, large at the anterior-most end,	42.13mm	Inc.	Inc.	Inc.
TMM 31173-109	Inc.	N/A	Inc.	Round, evenly spaced, good amount	Inc.	Inc.	Inc.	Inc.
TMM 31173-114	N/A	Inc.	N/A	Very uniform, round; large, even spacing	Inc.	Inc.	Inc.	Inc.
TMM 31172-25	Inc.	Inc.	Inc.	Small, round, space between each aveoli	at least 10.65mm	Inc.	Inc.	Inc.
TMM 31172-19	Inc.	Inc.	Inc.	Only anterior most aveoli visable, very	Inc.	Inc.	Inc.	Inc.
TMM 31173-81	Inc.	Inc.	Inc.	Very large anteriorly, small around 4-5, get	69.63mm	Inc.	Inc.	Inc.
TMM 31098-2	Inc.	Inc.	Inc.	Large anteriorly, small 5-8, get larger	~64.15mm	Inc.	Inc.	Inc.
TMM 31098-2								
TMM 31100-175	7.07mm	7.13mm	6.35mm	Medium sized and round, fairly even	41.27mm	533.0mm	345.0mm	Inc.
TMM 31100-	11.93mm	9.27mm	13.01mm	Mosly round	30.61mm	N/A	293.0mm	N/A

418				and uniform; some				
TMM 31100-1332	7.75mm	9.19mm	8.43mm	Many crushed or covered in mud so	33.14mm	511.0mm	257.0mm	134.9mm
TMM 31173-121	16.85mm	10.91mm	15.77mm	Fairly uniform and round, get larger as	44.27mm	624.0mm	371.5mm	114.9mm

Specimen Number	**Orbit Anterior/Posterior diameter**	**Skull width (across quadrates)**	**Postorbital length**	**Total skull length**
TMM 31173-120	83.0mm	293.5mm	72.5mm	931.5mm
TMM 31213-16	N/A	385.0mm	N/A	965.5mm
TMM 31025-56	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	Inc.	Inc.	Inc.
TMM 31025-179	Inc.	Inc.	Inc.	Inc.
TMM 31100-11	Inc.	Inc.	Inc.	Inc.
TMM 31100-126	Inc.	Inc.	Inc.	Inc.
TMM 31100-126	Inc.	Inc.	Inc.	Inc.
TMM 31100-463	Inc.	Inc.	Inc.	Inc.
TMM 31100-382	Inc.	Inc.	Inc.	Inc.
TMM 31100-12	Inc.	Inc.	Inc.	Inc.
TMM 31100-162	Inc.	Inc.	Inc.	Inc.
TMM 31100-318	Inc.	Inc.	Inc.	Inc.
TMM 31100-318	Inc.	Inc.	Inc.	Inc.
TMM 31100-286	Inc.	Inc.	Inc.	Inc.
TMM 31100-8	Inc.	257.0mm	~107.5mm	Inc.
TMM 31100-239	48mm	177.0mm	85.0mm	612.0mm
TMM 31185-43	Inc.	Inc.	Inc.	Inc.
TMM 31098-37	Inc.	Inc.	Inc.	Inc.
TMM 31098-18	Inc.	Inc.	Inc.	Inc.
TMM 31098-30	Inc.	Inc.	Inc.	Inc.
TMM 31098-30	Inc.	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	Inc.	Inc.	Inc.
TMM 31098-47	Inc.	Inc.	Inc.	Inc.
TMM 31100-1378	Inc.	Inc.	Inc.	Inc.

TMM 31100-1361	Inc.	Inc.	Inc.	Inc.
TMM 3100-1496	Inc.	Inc.	Inc.	Inc.
TMM 3100-1498	55mm	Inc.	Inc.	Inc.
TMM 3100-1497	Inc.	Inc.	Inc.	Inc.
TMM 31100-1495	Inc.	Inc.	Inc.	Inc.
TMM 31100-1020	Inc.	Inc.	Inc.	Inc.
TMM 43684-8	53mm	214.0mm	~120.0mm	N /A
TMM 43685-373	Inc.	Inc.	Inc.	Inc.
TMM 31173-7	Inc.	Inc.	Inc.	Inc.
TMM 31173-48	Inc.	Inc.	Inc.	Inc.
TMM 31173-51	Inc.	Inc.	Inc.	Inc.
TMM 31173-109	Inc.	Inc.	Inc.	Inc.
TMM 31173-114	Inc.	Inc.	Inc.	Inc.
TMM 31172-25	Inc.	Inc.	Inc.	Inc.
TMM 31172-19	Inc.	Inc.	Inc.	Inc.
TMM 31173-81	Inc.	Inc.	Inc.	Inc.
TMM 31098-2	Inc.	Inc.	Inc.	Inc.
TMM 31098-2				
TMM 31100-175	Inc.	Inc.	Inc.	Inc.
TMM 31100-418	N/A	Inc.	N/A	~670.0mm (not all parts of skull glued together)
TMM 31100-1332	71.0mm	246.0mm (estimated, part of bone missing)	143mm	816.0mm
TMM 31173-121	87.5mm	212mm (estimated part of bone missing)	224.0mm	998.7mm

Specimen Number	**Notes**
TMM 31173-120	medial/laterally crushed on the left side
TMM 31213-16	Too fragile to flip and get dorsal measurements
TMM 31025-56	Probably a juvenile, lots of space between alveoli
TMM 31025-179	No terminal rosette so can't number alveoli, some crushing of left maxillae
TMM 31025-179	Some alveoli missing, crushed or gapped due to restoration; no terminal rosette so can't number alveoli
TMM 31025-179	
TMM	Missing terminal rosette so I can't accurately number the teeth. I think the premax./max

31100-11	boundary is where the frag. Ends but not sure
TMM 31100-126	The right portion has been crushed to the side so many of the alveoli are not visible.
TMM 31100-126	Terrible crushing at the anterior most end of the premax., some teeth missing
TMM 31100-463	Alveoli are very difficult to distinguish, on left premax anterior-most end of the terminal rosette is missing so alveoli numbers are an approximation; can't even make approximation for right premax
TMM 31100-382	Two separate fragments so alveoli missing
TMM 31100-12	Huge diastema; probably should be re-prepared; rostrum ends at premax/max boundary
TMM 31100-162	Missing terminal rosette so can't accurately count alveoli; alveoli missing anterior, some crushing and missing pieces of bone throughout; other fragments in box but I believe I was told they were denary (can't remember)
TMM 31100-318	Maxillae in two fragments so cannot number alveoli; same specimen as next data entry
TMM 31100-318	Premax. In two fragments so can't accurately number alveoli; data entries are estimations; most anterior alveoli are difficult to see due to poor preservation; same specimen as previous data entry
TMM 31100-286	Maxillary length is an approximation because not entirely sure where premax/max boundary is; no terminal rosette so can't accurately label alveoli
TMM 31100-8	Specimen contains a lot of mud; dorsal-ventrally crushed so probably wider than normal
TMM 31100-239	Much of the postnarial skull is reconstructed with plaster
TMM 31185-43	Teeth were crushed at the most posterior end
TMM 31098-37	In 2 separate segments; most of maxillae is crushed or poorly preserved so alveoli hard to see; no terminal rosette so can't accurately number alveoli
TMM 31098-18	Missing terminal rosette so alveoli numbering is an approximation, plaster covering some alveoli; total rostrum width is an approximation
TMM 31098-30	Missing front of the premax. So cannot number the alveoli; since don't know alveoli 7 rostrum width is an approximation
TMM 31098-30	Missing front of premax. so unclear about the numbering of the alveoli; 5 different fragments, not sure how they go together; can't find the premax./max. boundary; anterior alveoli only partially there
TMM 31098-47	Missing ID #; restoration incomplete so still lots of dirt and hard to make out features; anterior-most part of premax missing so can't number alveoli; since not sure of alveoli 7 rostrum width is an approximation
TMM 31098-47	Missing ID #; restoration incomplete so still lots of dirt and hard to make out features; anterior-most part of premax missing so can't number alveoli
TMM 31100-1378	Not fully restored so very hard to identify features, anterior-most end of the premax. Missing so can't fully number alveoli
TMM 31100-1361	Not fully restored so very hard to identify features, anterior-most end of the premax. missing so can't fully number alveoli; hard to tell if there is an alveolar ridge or crest due to dirt
TMM 3100-1496	Alveoli become more ovular as you move posteriorly, end of fragment hard to see due to break and crushing
TMM 3100-1498	Specimen poorly preserved and covered in mud; anterior-most part of rostrum missing so can't number alveoli; part of bone surrounding the right orbit present
TMM 3100-1497	In 3 segments but I think they fit together. More crushed and poorer restoration as you move posteriorly; missing all id info

TMM 31100-1495	Phytosaur skulls present but no ID cards; just piece of middle of the rostrum so can't make any measurements other than alveoli count
TMM 31100-1020	Specimen too poorly preserved to gather much data. Most alveoli covered in mud
TMM 43684-8	Skull in fragments, severely crushed in sections and missing pieces so cannot recreate complete skull to get prenarial length or total skull length. Part of squamosals missing so postorbital length is an approximation; crushing also makes it hard to determine maxillary length
TMM 43685-373	What locality is PRO? Missing the premax/max suture so cannot number alveoli
TMM 31173-7	Not sure if maxillae or premax. Missing anterior most premax. so can't number alveoli
TMM 31173-48	Missing anterior most end so can't accurately number the alveoli
TMM 31173-51	Maybe one aveoli on the left filled in with plaster
TMM 31173-109	Terminal rosette missing so can't number alveoli, somewhat poor preservation
TMM 31173-114	Terminal rosette missing so can't number alveoli, large spaces between alveoli but very uniform
TMM 31172-25	Ridge seems present but because in two separate pieces can't determine if how wide the interpremax. Fossa is and can only approximate the total rostrum width; probably a juvenile; significant amount of plaster
TMM 31172-19	Most alveoli are not visible due to poor preservation of the rostrum
TMM 31173-81	Had difficulty finding the premax/max boundary, some alveoli are difficult to see due to missing bone; lots of plaster
TMM 31098-2	Poor preservation of many of the alveoli; total rostrum width is an approximation since the right side has plaster
TMM 31098-2	Needs more reconstruction before any measurements can be made; look at rostrum for more data
TMM 31100-175	Posterior end of skull missing including orbits so can't get any of those measurements
TMM 31100-418	missing id card; quadrates missing so can't measure skull width; too fragile to flip
TMM 31100-1332	Juvenile; posteriorly crushed so a little long; many of the alveoli covered in mud or crushed so difficult to get an accurate count; alveoli 15 on the right was crushed so used 14 for the measurement
TMM 31173-121	Dorsal ventrally crushed; had to lay on left side so left side measurements were difficult to obtain

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